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Facilities Storing or Treating Hazardous Waste in Tanks: A Technical Resource Document for Permit Writers

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The purpose of this manual is to provide guidance for permit writers in the implementation of Part 264, Subpart J, of the Code of Federal Regulations which sets forth regulations for facilities that use tanks to treat or store hazardous waste. The material is meant for guidance purposes only and is not meant to replace data and information that are specific to the facility being assessed.

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FACILITIES STORING OR TREATING HAZARDOUS WASTE IN TANKS

A Technial Resource Document for Permit Writers

This document (SW-XXX) was prepared by Fred C. Hart Associates, Inc., under contract to EPA's Office of Solid Waste and Theodore P. Senger of the Technology Branch, Hazardous & Industrial Waste Division, Office of Solid Waste.

This document has not been peer and administratively reviewed within EPA and is for internal Agency use/distribution only.

Stephen A. Lingle 11/2/82
Authorized signature and date

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PREFACE

This is one of a series of technical resource documents that provides information on standards for facilities that treat, store, or dispose of hazardous waste.

The documents are being developed to assist permit writers in evaluating facilities against standards (40 Code of Federal Regulations, Part 264) issued under Subtitle C of the Resource Conservation and Recovery Act (RCRA) of 1976, as amended. Included in these documents is detailed information about design, equipment, and specific procedures for evaluating data submitted by the permit applicant, as well as bibliographies that can be used to locate additional information.

The series, which is being produced by the Technology Branch of EPA's Office of Solid Waste, includes guidance on:

- containers
- tanks
- compatibility of wastes
- incineration

Permit writers should keep in mind when using this material that the regulations are subject to change through amendments and modifications and should incorporate any changes into their evaluations of facilities.

The material contained herein is for guidance purposes only and is not enforceable. The technical resource documents are not to be interpreted as amending the facility standards in 40 CFR Part 264.

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CHAPTER 1

INTRODUCTION

A. PURPOSE

The purpose of this manual is to provide guidance for permit writers in the implementation of Part 264, Subpart J, of the Code of Federal Regulations which sets forth regulations for facilities that use tanks to treat or store hazardous waste. The material is meant for guidance purposes only and is not meant to replace data and information that are specific to the facility being assessed.

B. THE PERMIT PROCESS

EPA's regulations provide for issuing hazardous waste facility permits in two phases: Part A of the permit application (interim status) and Part B of the permit application (permanent status--the final permit). Interim status allows facilities that are in existence to continue operations while administrative action on the final permit is under way. These facilities must submit Part B of the permit application upon request by EPA. New facilities must submit Part B of the permit application 180 days prior to beginning physical construction.

Part B of the permit application must contain information on the equipment, structures, and procedures used for managing hazardous waste at the facility. The application must also provide data on the physical and chemical characteristics of the wastes to be handled (40 CFR §122.25).

The permit writer evaluates the information provided in Parts A and B of the application to determine whether the facility meets the administrative technical standards (40 CFR 264) and the procedural requirements for obtaining a permit (40 CFR 122 and 124). To assist the permit writer, the Permit Guidance Manuals provide background information and procedures for evaluating the data provided by the applicant.

The RCRA administrative procedures permit manual (SW-934) provides guidance to permit writers on procedures to follow from the point of initial contact with an applicant through review, public hearings, and any administrative appeals of permit decisions. The manual also contains guidance for conducting technical reviews.

C. CONCEPT OF BEST ENGINEERING JUDGMENT (BEJ)

Various sections of the final regulation for tank treatment and storage require the use of best engineering judgment (BEJ). This concept entails the application of a case-by-case judgment, based on site-specific circumstances, to facilities attempting to meet permit requirements. In those sections of the regulations that have been written based on BEJ, some flexibility is provided in developing permit requirements. The Agency feels that the evaluation of facilities on an individual basis will provide the greatest protection to human health and the environment and at the same time avoid overly restrictive requirements.

BEJ provides for tailoring permit requirements to the specific wastes and the design and environmental conditions of each facility based on the best engineering judgment of the permit writer. In order to make these judgments, the permit writer must have access to information on current technology and be provided with facility and site-specific data.

D. REGULATIONS

Section 3004 of RCRA directs EPA to develop standards for owners and operators of hazardous waste treatment, storage, and disposal facilities. Under this directive EPA promulgated regulations for the treatment and storage of hazardous waste in tanks (40 CFR 264). Tanks are defined in 40 CFR 260 (45 Fed. Reg. 33076 [May 19, 1980]) to be a "stationary device, designed to contain an accumulation of hazardous waste which is constructed primarily of non-earthen materials...which provide structural support."

This manual discusses the regulations pertaining to treatment and storage of hazardous wastes in tanks (40 CFR, Part 264 Subpart J). The following areas are covered:

- design of tanks (§264.191)
- general operating requirements (§264.192)
- inspections (§264.194)
- closure (§264.197)
- special requirements for ignitable or reactive wastes (§264.198)
- special requirements for incompatible wastes (§264.199)

E. ORGANIZATION OF THE MANUAL

Chapter 1 provides an overview of the manual. It outlines the areas that the RCRA hazardous waste tank regulation covers and describes the content of each chapter.

Chapter 2 is comprised of questions that are directly related to the regulations. These questions are designed to serve as a checklist for a permit writer during the evaluation of a permit application. Answers to the questions will facilitate the decision-making process of whether or not an applicant will be able to comply with the RCRA regulations.

Chapter 3 presents a discussion of the factors that influence tank design and selection. Structural integrity and compatibility are discussed as they relate to the expected service life of the tank. The importance of pressure upon the tank structures is presented. Corrosion rate, corrosion allowances, and lining and coatings as a protection against corrosion are examined. Design features necessary for safe operation of a tank facility conclude the chapter.

Chapter 4 includes external and internal visual inspection points where a tank and its auxiliary equipment should be inspected. Techniques used to perform inspections are listed, and the rationale for determining inspection frequencies is outlined.

Chapter 5 addresses possible interactions of tank materials and wastes or treatment reagents (or processes). Five common treatment processes are described with emphasis upon the interactions of the treatment processes and the tank materials. The treatment processes are: (1) chemical oxidation, (2) chemical reduction, (3) neutralization, (4) precipitation, and (5) sedimentation.

Chapter 6 addresses the evaluation of a tank closure plan. Disposal procedures for onsite waste and waste residues are described, followed by decontamination procedures.

Chapter 7 discusses basic materials and costs, operating and maintenance costs, and capital costs of constructing and operating a tank facility.

The appendices provide general information on tank storage facilities.

CHAPTER 2

CHECKLIST AND QUESTIONS TO BE ASKED BY PERMIT WRITERS

A. CHECKLIST FOR PERMIT WRITERS

This section provides the permit writer with a checklist for evaluating an application from an owner or operator of a hazardous waste facility utilizing tanks for storage or treatment. The checklist can be used to determine the completeness and adequacy of the permit application.

1. General Facility Description

   - number of tanks
   - location of tanks
   - buffer zones around tanks (Note: §264.198 requires compliance with National Fire Protection Association's buffer zone requirements)

2. Chemical and Physical Analyses of Wastes

   - information necessary to determine waste-to-waste compatibility, waste-to-tank compatibility, and ignitability or reactivity

3. Waste Analysis Plan

   - analyses used to determine characteristics and properties of the waste to be stored or treated
   - analyses needed for compliance with requirements for ignitable, reactive, or incompatible wastes
   - methods to obtain representative samples of waste
   - frequency with which original analysis will be reviewed or repeated
   - source of other information on properties or characteristics of waste for offsite facilities
   - procedures to be used to inspect each shipment of waste received at the facility

4. Description of Security

5. Inspection Schedule

- schedule for inspection of monitoring equipment, safety and emergency equipment, and security devices, specified in §§264.15 and 264.194(a)
- schedule for comprehensive inspections and assessments of the condition of the tanks required in §264.194(b)
- list of items to be covered during routine external inspection (e.g., cracks, leaks, corrosion, erosion of foundation or tank sides or bottoms, deterioration of foundation seal, corrosion or discoloration of tank exterior, etc.)
- procedures for comprehensive inspections required in §264.194(b)
  - procedures for inspecting internal surfaces
  - safety procedures for protecting inspector

6. Justification for Waiver of Preparedness and Prevention Requirements

7. Contingency Plan
   - actions to be taken in response to fires, explosions, or unplanned releases of hazardous waste, including procedures and timing for removal of waste and repair of tank as required by §264.194(c).
   - arrangements with police department, fire department, hospitals, contractors, and State and local emergency response teams
   - list of emergency coordinators at the facility
   - list and location of emergency equipment
   - evacuation plan, if necessary

8. Description of Procedures to:
   - prevent hazards in unloading
   - prevent runoff from handling areas
   - prevent contamination of water supplies
   - mitigate effects of equipment failure and power outages
   - prevent exposure of personnel to hazardous waste

9. Incompatible, Ignitable, and Reactive Wastes

- procedures for treating waste prior to placement in tank, where applicable
- procedures used to prevent a waste from being placed in an unwashed tank that previously held an incompatible waste
- procedures used to prevent incompatible wastes from being placed in the same tank
- documentation of precautions to prevent accidental ignition or reaction (§264.198(a))
- documentation of compliance with NFPA buffer zone requirements (§264.198(b))
- for offsite facilities, procedures for inspecting each shipment of waste received (part of the waste analysis plan)

10. Traffic Pattern and Volume

11. Facility Location

- political jurisdiction in which facility is located
- if facility is in an area listed in Appendix VI of Part 264, demonstration of compliance with the seismic standard (see §§264.18(a) and 122.25(a)(11)(ii) for details)
- identification of whether facility is located in a 100-year floodplain
- if facility is in a 100-year floodplain, engineering analyses showing design of operational units and flood protection devices and their ability to withstand forces of a 100-year flood, or procedures for removing hazardous waste prior to a flood (see §§264.18(b) and 122.25(a)(11)(iv) for details)
- if existing facility is not in compliance with §264.18(b), a plan and schedule for bringing facility into compliance

12. Outline of Training Programs

13. Closure Plan (see §264.122)

14. Closure Cost Estimate and Financial Assurance Mechanism (§264.142 and 264.143)

15. Documentation of Compliance with Liability Requirements, if applicable (§264.147)

16. Proof of Coverage by State Financial Mechanism, Where Appropriate (§§264.149 or 264.150)

17. Topographic Map (§122.25(a)(19))

18. Design Information for Each Tank:

- design standard and other engineering information used in design; construction

- identification of and specifications for construction materials and lining materials including information on corrosion resistance

- tank dimensions, capacity, and shell thickness

- description of feed, cutoff, and bypass systems and pressure controls

  - description of devices for measuring liquid level of flow rate

  - description of overfilling controls (e.g., alarm or cutoff)

  - design standard or other information used in design of pressure controls (e.g., vents)

B. QUESTIONS TO BE ANSWERED BY PERMIT WRITERS

The following questions can be used by the permit writer in in evaluating the information in the permit application and preparing a facility permit.

1. Tank Design

   a. Do nonearthen materials provide the structural support (is it a tank?)?

   b. What is the minimum required thickness of the tank walls based on the design standard or other engineering information?

   c. Is sufficient vapor space provided to allow vapors to expand when the ambient temperature rises?

   d. Are adequate vents provided for pressure relief to atmosphere or vapor recovery system?

2. Compatibility of Waste with Tank

   a. Does the waste analysis plan specify adequate procedures for determining whether the waste is compatible with the tank construction materials or lining materials?

   b. Are the tank construction materials or lining materials compatible with the waste stored?

   c. Are corrosion inhibitors or cathodic protection used to protect the tank material against attack?

   d. Are the assumed corrosion rates of the material of construction of the tank based on published literature or submitted data?

   e. Based on the estimated corrosion rate and present thickness of the tank, what is the expected service life of the tank?

3. Overfilling Controls

   a. Is the tank equipped with adequate controls to prevent overfilling (e.g., high-level alarms, automatic feed cutoff system, by-pass system to a stand-by tank, etc.)?

4. Inspection

   a. Does the inspection schedule include the components required by §264.194(c)?

   b. Are the procedures for the comprehensive inspections required by §264.194(b) adequate to detect cracks, leaks, corrosion, and wall thinning.

   c. Are adequate procedures specified for protecting the inspector while inside the tank (if appropriate)?

   d. Is the frequency of inspections based on the estimated corrosion rate and service life of the tank?

   e. Are procedures for responding to spills and repairing the tank specified in the contingency plan?

5. Closure

   a. What are the expected general conditions of the tank at closure?

      - types of wastes stored

      - maximum inventory

b. What are the schedule and estimated cost of closure activities?

c. How will the wastes be removed from the tanks?

d. Will the the wastes be treated, stored, or disposed of onsite or offsite?

e. How will the tank and associated equipment be decontaminated?

f. How will contaminated soils, cleaning products, and residues be disposed of?

6. Ignitable, Reactive, and Incompatible Wastes

a. Do the procedures for management of ignitable, reactive, and incompatible wastes satisfy the requirements of §§264.17, 264.36, 264.198, and 264.199? (See checklist item 19.)

CHAPTER 3

TANK DESIGN

Chapter Outline

A. Introduction

B. Tank Design Considerations

- 1. Internal Pressure and Pressure Controls

    - a. Pressure
    - b. Venting

- 2. Minimum Wall Thickness and Compatability of Construction Materials with Waste

    - a. Construction Materials
    - b. Mimimum Thickness and Corrosion Allowances
    - c. Expected Service Life
    - d. Examples
    - e. Decision Process

C. Ancillary Design Features Necessary for Safe Operations

- 1. Measurement Devices
- 2. Overfilling Control Systems

D. Diagrams of Process Flow and Instrumentation

- 1. Process Flow Diagrams
- 2. Piping and Instrumentation Diagrams
- 3. Plot Plans
- 4. Tank Diagrams and Data Sheets

CHAPTER 3

A. INTRODUCTION

The RCRA Subtitle C regulations define a tank as a "stationary device, designed to contain an accumulation of hazardous waste which is constructed primarily of non-earthen materials (e.g., wood, concrete, steel, plastic) which provide structural support."[1] Liquid and semiliquid hazardous wastes are often stored or treated in tanks, of which there is a variety of types and sizes.

Factors to consider when evaluating tank design include:

Tank Design Basis

- design standards used
- other engineering information

Compatibility of Waste with Tank or Lining

- composition of waste
- construction materials of the tank
- corrosion rate of waste with respect to construction material
- expected service life of tank

Operating Conditions

- pressure exerted on walls of tank
- temperature

Other Factors

- climate
- corrosivity of surrounding soil

These factors (with the exception of climate and soils) are discussed in the remainder of the chapter.

B. TANK DESIGN CONSIDERATIONS

The three major considerations in designing a tank to store a particular hazardous waste are:

- internal vapor pressure
- stress caused by weight of contents
- compatibility of construction material with the waste stored

Internal pressure is discussed in the following section. A discussion of strength and of compatibility of the tank with the wastes stored is presented later in this chapter. Additional information on compatabilities between waste and structural materials is contained in the technical resource document on waste compatibility.[2]

1. Internal Pressure and Pressure Controls

a. Pressure. Pressure imbalances affect the safe operation of a storage tank and, in extreme cases, can result in instantaneous tank rupture. The petroleum and chemical industries have historically based the primary selection of storage tanks on design pressures. Currently, there are well-accepted industrial design standards and codes for storing different types of liquids. Among the most common are the following:

- the design of welded steel tanks up to 2.5 pounds per square inch gauge (psig) internal pressure is covered by the American Petroleum Institute (API) standard 620[4]
- the design of large welded, low-pressure storage tanks up to 15 psig is covered by API standard 620[4]
- the design of water storage reservoirs, steel tanks, and elevated tanks is covered by the American Water Works Association (AWWA) Code D100[5]
- the design of tanks with internal pressures above 15 psig and below 0 psig (vacuum tanks) is covered by the American Society of Mechanical Engineers (ASME) pressure vessel code[6]
- tank design for flammable and combustible liquid storage is covered by the National Fire Protection Association (NFPA), Pamphlet No. 30[7]
- the design of steel above-ground tanks for flammable and combustible liquids is covered by Underwriters' Laboratories, Inc., Subject No. 142[8]
- the design of open concrete tanks is covered by American Concrete Institute Publication ACI-350-R-77[9]

The American Petroleum Institute classifies tanks into three major divisions based on pressure. "Atmospheric tanks" are designed to contain pressures up to 2.5 psig and are structurally different from "low-pressure tanks" designed to withstand up to 15 psig. "High-pressure tanks" are designed to withstand pressures greater than 15 psig.

- Liquid hazardous wastes are most commonly stored in covered atmospheric or low-pressure, above-ground tanks. High-pressure, vacuum, and underground tanks are not covered in detail in this chapter. Table 3-1 lists the most commonly used types of tanks and selection considerations pertinent to each type of tank. Appendix A presents descriptions of the tanks listed in Table 3-1.

TABLE 3-1

TANK SELECTION CONSIDERATIONS

Type of Tank	Pressure	Other Considerations
I. Atmospheric, Above-ground, Covered Tanks	0 to 2.5 pounds per square inch gauge (psig)	
a) Plain cylindrical		Nominal vapor pressure fluctuations, small volume
b) Fixed-roof		Nominal vapor pressure fluctuations
c) Variable vapor-space		Moderate vapor pressure fluctuations
d) Breather roof		Moderate vapor pressure fluctuations
e) Floating roof		Significant vapor pressure fluctuations
f) Covered floating roof		Significant vapor pressure fluctuations plus heavy rainfalls or snowfalls
II. Low-Pressure, Above-ground, Covered Tanks	Up to 15 psig	
a) Hemispheroidal		Small-to-medium volumes
b) Spheroidal		Large volumes
c) Noded-spheroidal		Very large volumes
III. Underground Tanks	Generally 0 psig	Small volume, aesthetics, safety Not currently allowed at permitted treatment or storage facilities
IV. Uncovered Tanks	Atmospheric pressure (0 psig)	No volatile pollutants

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* Source: Fred C. Hart Associates, Inc.

On the basis of the pressure criterion, an owner or operator can select an atmospheric, above-ground, covered tank to store most hazardous wastes. Hazardous wastes that are highly volatile and capable of exerting pressure higher than 2.5 psig should be stored in low-pressure tanks.

The following general guidelines will aid in evaluating the proper selection of tanks to store hazardous waste based on a pressure criterion:

- Pressurized tanks are used to store hazardous wastes that have toxic vapors. If the waste is nonvolatile or the vapors nonpolluting, atmospheric tanks can be used to store hazardous wastes.
- Storage of liquid hazardous waste seldom requires the utilization of high-pressure tanks (above 15 psig) or tanks operating under vacuum.
- Uncovered tanks are not recommended for storage of hazardous wastes unless the wastes are nonvolatile.
- Wastes with low boiling points (such as heavy metal-laden pentane, which has a boiling point of 37°C) tend to vaporize easily and exert higher vapor pressure. If the vapor pressure of the waste is above 2.5 psig, the waste should be stored in low-pressure tanks.
- Vapor pressure of the waste at maximum ambient temperature must be known. The permit writer can then determine whether or not the tank is selected properly on the basis of pressure.

b. Venting. Vents for tanks perform two general functions:

- Allow air, inert gas, or other blanket gas into the tank or allow vapor to escape from the tank. In this manner the vapor pressure of the tank will be maintained either under atmospheric pressure or within the pressure limitation of the tank design to preclude rupture or collapse of the tank.
- Serve as a discharge point to allow the collection of either undesirable vapor emissions (i.e., hazardous pollutants or other air pollutants) or vapors that can be recovered and sold as a commercial product (e.g., methane).

Venting designs of a tank facility are determined by the types of wastes handled, pumping requirements, etc. Venting designs include:

(1) Maintaining Atmospheric or Design Pressure. Maintaining internal tank pressure either equal to outside atmospheric pressure or within the desired pressure of the tank is critical to the safe operation of a tank facility. When liquid is drained out of the bottom of a tank, a vacuum may be created in the space left above the remaining liquid. This may cause the collapse of the tank owing to the pressure differential. Vents must be designed to allow air or other gas into the tank as liquid is removed. This maintains the internal pressure of the tank. Vent sizes should be determined according to industrial standards such as APE standard 2000.[10]

Vents also serve to release vapor from a tank when it is being filled. Vents open to the ambient air are usually used for tanks containing wastes whose vapors are not considered to be toxic or highly flammable. Control of air emissions from hazardous waste tanks will be addressed in future regulations and guidance.

(2) Venting/Vapor Recovery Systems. Vapor recovery systems have sophisticated pressure sensing and pressure control instrumentation that maintains vapor pressure equilibrium during all periods of tank operation. Vapor recovery systems consist of a system to collect the vapors frequently followed by a treatment process that either renders the vapor harmless for venting to the atmosphere or converts it to a product that has market value. Common treatment methods include compression, absorption, and condensation. If the product has no value, it can be disposed of by flaring, incineration, or other methods. Two configurations of vapor recovery units are used: 1) individual units for each tank; and 2) common vapor recovery units for a system of two or more tanks that are being used to store wastes with similar vapor chemical compositions.

The following items should be considered when evaluating venting/vapor recovery systems:

- When more than one type of waste is handled, their compatibility must be determined. When the wastes are incompatible, their vapors may also be incompatible. Separate vapor recovery units would be appropriate.
- Vapor recovery systems must be maintained at airtight conditions to preclude leakage.
- The control instrumentation should be adequately monitored and maintained on an appropriate schedule.
- The vapor recovery pipes should be sloped down to a common place where condensation can be collected. In addition, the vapor flow linear velocity must be maintained under design limitations to preclude excessive turbulence, vibration, etc.

The permit writer should review the process flow diagram (i.e., a diagram that depicts the direction and volume of vapor and fluid movements) to evaluate factors such as the following:

- Is there a vapor recovery system or other method of recovery to accommodate incompatible wastes? (Incompatible wastes should not utilize a common vapor recovery system.)
- If incompatible wastes are going to be handled, are there separate piping systems?

2. Minimal Wall Thickness and Compatibility of Construction Materials with Waste

The walls (or shell) of the tank must be of sufficient thickness and strength to withstand the stresses caused by the weight of the tank contents. Because corrosion reduces the thickness of the tank shell, maintaining sufficient thickness and strength necessitates consideration of the compatibility between the contained waste and the tank construction material. This section discusses the compatibility of tank construction materials and wastes, minimum tank shell thickness and corrosion allowances, and the expected service life of a tank based on estimated corrosion rates.

a. Construction Material. Materials used for tank construction include steel, concrete, plastic, and wood. Most tanks currently in use are made of carbon steel and alloy steel. Plastic and wood tanks are not discussed in this section.[11]

(1) Steel Used in Tanks. Some of the features of carbon and alloy steels are listed below. Table 3-2 summarizes the general corrosion properties of a wide range of metals and alloys.

(a) Carbon steels

- most commonly used steel in the petroleum and chemical industries
- can be used to store alkalies; for example, caustic soda can be stored in concentrations up to 75 percent at temperatures ranging to 212°F
- only slightly subject to corrosion by brines and sea water
- commonly used to store organic solvents and similar chemicals

TABLE 3–2

General Corrosion Properties of Some Metals and Alloys*

Ratings: 0 unsuitable. Not available in form required or not suitable for fabrication requirements or not suitable for corrosion conditions.
1 poor to fair.
2 fair. For mild conditions or where periodic replacement is possible. Restricted use.
3 fair to good.
4 good. Suitable when superior alternatives are uneconomic.
5 good to excellent.
6 normally excellent.
Small variations in service conditions may appreciably affect corrosion resistance. Choice of materials is therefore guided wherever possible by a combination of experience and laboratory and site tests.

Material	Liquids: Non-oxidizing or reducing media				Oxidizing media			Natural waters				Gases: Common industrial media				
			Alkaline solutions, e.g.,					Fresh-water supplies		Sea water		Steam		Furnace gases with incidental sulfur content		
	Acid solutions, including hydrochloric, e.g., phosphoric, sulfuric, most conditions, many organics	Neutral solutions, e.g., many non-oxidizing salt solutions, chlorides, sulfates	Caustic and mild alkalies, excluding ammonium hydroxide	Ammonium hydroxide and amines	Acid solutions, e.g., nitric	Neutral or alkaline solutions, e.g., persulfates, peroxides, chromates	Pitting media, acid ferric chloride solutions	Static or slow-moving	Turbulent	Static or slow-moving	Turbulent	Moist, condensate	Dry at high temp., promoting slight dissociation	Reducing, e.g., heat-treatment furnace gases	Oxidizing, e.g., flue gases	Ambient air, dry or industrial
Cast iron, flake graphite, plain or low alloy	1	3	4	5	0	4	0	4	3	4	3	4	4	1	1	3
Ductile iron (higher strength and hardness may be obtained by composition and heat-treatment or both)	1	3	4	5	0	4	0	4	4	4	3	4	4	1	1	3
Ni-Resist corrosion-resistant cast iron, type 1 (14 Ni; 7 Cu; 2 Cr; bal. Fe)	4	3	3	3	0	3	0	3	3	3	3	5	3	3	2	4
Ni-Resist corrosion-resistant cast iron, type 2 Cu free (20–30 Ni; 2–5 Cr; bal. Fe)	4	3	3	6	0	3	0	3	3	3	3	5	5	3	2	4
Ni-Resist corrosion-resistant cast iron, ductile (20 Ni; bal. Fe)	2	3	3	5	0	3	0	3	3	3	3	3	3	3	3	3
14% silicon iron	6	6	1	3	6	6	3	3	3	3	3	6	4	4	3	6
Mild steel, also low-alloy irons and steels	1	3	4	3	0	4	0	4	3	4	3	4	4	1	1	3
Stainless steel, ferritic 17% Cr type	2	4	4	6	5	6	0	4	4	1	4	5	6	3	2	4
Stainless steel, austenitic 18 Cr; 8 Ni type	3	4	3	6	6	6	0	6	6	2	5	6	6	2	3	5
Stainless steel, austenitic 18 Cr; 12 Ni; 2.5 Mo type	4	5	3	6	5	6	1	6	6	3	3	6	6	3	4	6
Stainless steel, austenitic 20 Cr; 29 Ni; 2.5 Mo; 3.5 Cu type	5	6	5	6	5	6	2	6	6	4	6	6	6	2	4	6
Ni-o-nel nickel-iron-chromium alloy (40 Ni; 21 Cr; 3 Mo; 1.5 Cu; bal. Fe)	6	6	3	6	3	6	2	6	6	4	6	6	6	3	3	6
Hastelloy alloy C[a] (55 Ni; 17 Mo; 16 Cr; 6 Fe; 4 W)	5	6	3	6	4	6	3	6	6	4	6	6	6	3	4	6
Hastelloy alloy B[b] (61 Ni; 28 Mo; 6 Fe)	6	3	4	4	0	5	0	6	6	4	4	6	3	3	2	5
Hastelloy alloy D (85 Ni; 9 Si; 3 Cu)	6	6	3	4	2	5	1	6	6	4	6	6	6	4	3	6
Inconel nickel-chromium alloy (78 Ni; 15 Cr; 7 Fe)	3	6	4	6	3	6	1	6	6	4	6	6	6	2	4	6

[a] Also Chlorimet 3. [b] Also Chlorimet 2.

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TABLE 3-2

General Corrosion Properties of Some Metals and Alloys*—(Continued)

Ratings: 0 unsuitable. Not available in form required or not suitable for fabrication requirements or not suitable for corrosion conditions.
1 poor to fair.
2 fair. For mild conditions or where periodic replacement is possible. Restricted use.
3 fair to good.
4 good. Suitable when superior alternatives are uneconomic.
5 good to excellent.
6 normally excellent.
Small variations in service conditions may appreciably affect corrosion resistance. Choice of materials is therefore guided wherever possible by a combination of experience and laboratory and site tests.

Material	Liquids											Gases				
	Non-oxidizing or reducing media				Oxidizing media			Natural waters				Common industrial media				
	Acid solutions, including hydrochloric, e.g., phosphoric, sulfuric, and mild oxidizing, many organics	Neutral solutions, e.g., many non-oxidizing salt solutions, chlorides, sulfates	Alkaline solutions, e.g.		Acid solutions, e.g., nitric	Neutral or alkaline solutions, e.g., persulfates, peroxides, chromates	Pitting media, acid ferric chloride solutions	Fresh-water supplies		Sea water		Steam		Furnace gases with incidental sulfur content		Ambient air, city or industrial
			Caustic and mild alkalies, excluding ammonium hydroxide	Ammonium hydroxide and amines				Static or slow-moving	Turbulent	Static or slow-moving	Turbulent	Moist, condensate	Dry at high temp., promoting slight dissociation	Reducing, e.g., heat-treatment furnace gases	Oxidizing, e.g., flue gases	
Copper-nickel alloys up to 30% nickel	4	5	5	0	0	4	1	6	6	6	6	6	5	3	2	5
Monel (R) nickel-copper alloy (66 Ni; 30 Cu; 1 Fe)	5	6	6	1	0	5	1	6	6	6	6	6	6	3	5	5
Alloy 505 nickel-copper cast alloy (64 Ni; 30 Cu; 4 Si)	5	6	6	1	0	5	1	6	6	6	6	6	6	3	5	5
Monel K-500 age hardenable Ni-Cu alloy (67 Ni; 30 Cu; 3 Al)	5	6	6	1	0	5	1	6	6	6	6	6	6	3	5	5
A nickel—commercial (99.4 Ni)	6	5	6	1	0	3	0	6	6	5	3	6	6	3	5	6
Copper and silicon bronze	4	4	4	0	0	4	0	6	5	4	1	6	5	3	3	5
Aluminum brass (76 Cu; 22 Zn; 2 Al)	5	4	3	0	0	5	0	6	6	4	3	6	5	3	3	5
Nickel aluminum bronze (80 Cu; 10 Al; 5 Ni; 5 Fe)	4	4	3	0	0	5	0	6	6	4	5	6	5	3	3	5
Bronze, type A (88 Cu; 5 Sn; 5 Ni; 2 Zn)	4	5	4	0	0	4	0	4	5	5	5	4	5	3	3	5
Aluminum and its alloys	1	5	0	0	0–3	0–4	0	4	5	0–3	4	5	3	3	3	5
Lead, chemical or antimonial	5	5	3	3	0	3	0	6	5	5	5	3	0	4	5	5
Silver	4	6	6	0	0	3	0	6	6	5	5	6	5	4	4	4
Titanium	5	6	3	6	6	6	6	6	6	6	6	6	5	5	5	6
Zirconium	3	6	3	6	6	6	3	6	6	6	6	6	6	3	3	6

TABLE 3-2

General Corrosion Properties of Some Metals and Alloys[*]—(Continued)

Ratings: 0 unsuitable. Not available in form required or not suitable for fabrication requirements or not suitable for corrosion conditions.
1 poor to fair.
2 fair. For mild conditions or where periodic replacement is possible. Restricted use.
3 fair to good.
4 good. Suitable when superior alternatives are uneconomic.
5 good to excellent.
6 normally excellent.
Small variations in service conditions may appreciably affect corrosion resistance. Choice of materials is therefore guided wherever possible by a combination of experience and laboratory and site tests.

Material	Gases (Cont'd.)				Available forms	Cold formability in wrought and clad form	Weldability	Max. strength annealed condition × 1000 lb./sq. in.	Coeff. of thermal expansion, millionths per °F, 70°-212°F.	Remarks¶
	Halogens and derivatives									
	Halogens		Halide acids, e.g., hydrochloric hydrolysis products of organic halides	Hydrogen halides, dry,‡ e.g., dry hydrogen chloride, °F.						
	Moist, e.g., chlorine below dew point	Dry, e.g., fluorine above dew point								
Cast iron, flake graphite, plain or low alloy	0	3	0	1 < 400 1 < 750	Cast	No	Fair§	45	6.7	
Ductile iron (higher strength and hardness may be attained by composition and heat-treatment or both)	0	3	0	1 < 400 1 < 750	Cast	No	Good§	67	7.3	
Ni-Resist corrosion-resistant cast iron, type 1 (14 Ni; 7 Cu; 2 Cr; bal. Fe)	0	2	3	3 < 400 3 < 750	Cast	No	Good§	23-34	10.3	
Ni-Resist corrosion-resistant cast iron, type 2 Cu free (20-30 Ni; 2-5 Cr; bal. Fe)	0	2	3	3 < 400 3 < 750	Cast	No	Good§	22-34	9.6	Type 3 Ni-Resist has same corrosion resistance
Ni-Resist corrosion-resistant cast iron, ductile (20 Ni; bal. Fe)	0	2	3	3 < 400 3 < 750	Cast	No	Good§	56	10.4	
14% silicon iron	0	0	4	1 < 400	Cast	No	No	23	7.4	Very brittle, susceptible to cracking by mechanical and thermal shock
Mild steel, also low-alloy irons and steels	0	3	0	3 < 400 1 < 750	Wrought, cast	Good	Good	67	6.7	High strengths obtainable by alloying, also improved atmospheric corrosion resistance. See A.S.T.M. specifications for particular grade
Stainless steel, ferritic 17% Cr type	0	2	0	2 < 400	Wrought, cast, clad	Good	Good§	75	6.0	A.I.S.I. type 430 A.S.T.M. corrosion- and heat-resisting steels
Stainless steel, austenitic 18 Cr; 8 Ni types	0	2	0	3 < 400	Wrought, cast, clad	Good	Good	90	9.6	A.I.S.I. type 304 A.S.T.M. corrosion- and heat-resisting steels. Stabilized or ELC types used for welding
Stainless steel, austenitic 18 Cr; 12 Ni; 2.5 Mo type	0	3	2	4 < 400 3 < 750	Wrought, cast, clad	Good	Good	90	8.9	A.I.S.I. type 316 A.S.T.M. corrosion- and heat-resisting steel. ELC type used for welding
Stainless steel, austenitic 20 Cr; 29 Ni; 2.5 Mo; 3.5 Cu type	1	3	3	4 < 400 3 < 750	Wrought, cast	Good	Good	90	9.4	A.C.I. CN 7M. Good resistance to sulfuric, phosphoric, and fatty acids at elevated temperatures
Ni-o-nel nickel-iron-chromium alloy (40 Ni; 21 Cr; 3 Mo; 1.5 Cu; bal. Fe)	2	3	3	4 < 400 3 < 750	Wrought, cast, clad	Good	Good	100	7.3	Special alloy with good resistance to sulfuric, phosphoric, and fatty acids. Resistant to chlorides in some environments
Hastelloy alloy C[a] (55 Ni; 17 Mo; 16 Cr; 6 Fe; 4 W)	5	4	4	4 < 750 3 < 900	Wrought, cast, clad	Fair	Good	145	6.3	Excellent resistance to wet chlorine gas and sodium hypochlorite solutions
Hastelloy alloy B[b] (61 Ni; 28 Mo; 5 Fe)	1	3	5	4 < 750 3 < 900	Wrought, cast, clad	Fair	Good	135	5.6	Resistant to solutions of hydrochloric and sulfuric acids
Hastelloy alloy D (82 Ni; 9 Si; 3 Cu)	1	1	2	3 < 400 2 < 750 1 < 900	Cast	No	§	90-110	6.1	Greatest application in hot concentrated solutions of sulfuric acid
Inconel nickel-chromium alloy (76 Ni; 15 Cr; 7 Fe)	2	3	3	5 < 400 4 < 900	Wrought, cast, clad	Good	Good	90	8.9	Wide application in food and pharmaceutical industries

[a] Also Chlorimet 3. [b] Also Chlorimet 2.

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TABLE 3-2

General Corrosion Properties of Some Metals and Alloys*—(Concluded)

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1 poor to fair.
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6 normally excellent.
Small variations in service conditions may appreciably affect corrosion resistance. Choice of materials is therefore guided wherever possible by a combination of experience and laboratory and site tests.

Material	Gases (Cont'd)				Available forms	Cold formability in wrought and clad form	Weldability	Max. strength annealed condition × 1000 lb./sq. in.	Coeff. of thermal expansion, millionths per °F., 70°-212°F.	Remarks¶
	Halogens and derivatives									
	Halogens		Halide acids, moist, e.g., hydrochloric, hydrolysis products of organic halides	Hydrogen halides, dry,† e.g., dry hydrogen chloride, °F.						
	Moist, e.g., chlorine below dew point	Dry, e.g., fluorine above dew point								
Copper-nickel alloys up to 30% nickel	1	5	3	<400 <750	Wrought, cast, clad	Good	Good	38-62	8.5-9.5	High-iron types excellent for resisting high-velocity effects in condenser tubes
Monel 400 nickel-copper alloy (66 Ni; 30 Cu; 2 Fe)	2	6	3	<400 <750 <900	Wrought, cast, clad	Good	Good	77	7.8	Widely used for sulfuric acid pickling equipment. Also for propeller shafts in motor boats. Take precautions to avoid sulfur attack during fabrication
Alloy 505 nickel-copper cast alloy (64 Ni; 30 Cu; 4 Si)	2	6	3	<400 <750 <900	Cast	No	No	100	8.0	Non-galling characteristics. Excellent for bearings or bushings. High strength developed by heat-treatment
Monel K-500 age hardenable Ni-Cu alloy (67 Ni; 30 Cu; 3 Al)	2	6	3	<400 <750 <900	Wrought, cast	Fair	Good	99-155	7.9	High strength obtainable by heat-treatment. Take precautions to avoid sulfur attack during fabrication
A nickel—commercial (99.4 Ni)	2	6	2	<400 <750 <900	Wrought, cast, clad	Good	Good	54	6.6	Widely used for hot concentrated caustic solutions. Take precautions to avoid sulfur attack during fabrication
Copper and silicon bronze	0	5	2	<400 <750	Wrought, cast, clad	Excellent	Fair	29	9.3-9.5	Unsuitable for hot concentrated mineral acids or for high-velocity HF
Aluminum brass (76 Cu; 22 Zn; 2 Al)	0	4	2	<400	Wrought, cast	Good	Fair	60	10.3	May develop localized corrosion in sea water
Nickel-aluminum-bronze (80 Cu; 10 Al; 5 Ni; 5 Fe)	0	4	3	<400 <750	Wrought, cast	Good	Fair	60-80	9.4	Ship propellers an excellent application
Bronze, type A (88 Cu; 5 Sn; 5 Ni; 2 Zn)	0	4	3	<400 <750	Cast	No	—	45	11.0	High strengths obtainable by heat-treatment. Not susceptible to dezincification
Aluminum and its alloys	0	6	6	<400 <750	Wrought, cast, clad	Good	Good	9-90	11.5-13.7	Extent of corrosion dependent upon type and concentration of acid/halogen. Wide range of mechanical properties obtainable by alloying and heat-treatment
Lead, chemical or antimonial	0	1	3	0	Wrought, cast, clad	Excellent	Good	2	16.4-16.1	High purity "chemical lead" preferred for most applications
Silver	3	5	3	<400 <750	Wrought, cast, clad	Excellent	Good	25	10.6	Used as a lining
Titanium	6	0	1	0	Wrought, cast	Fair	Good§	6-90	5.0	Red fuming HNO_3 may initiate explosions. Good resistance to solutions containing chlorides
Zirconium	6	1	6	0	Wrought, cast	Fair	Good§			

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*Data courtesy of International Nickel Co.
† On unsuitable materials these media may promote potentially dangerous pitting.
‡ Temperatures are approximate.
§ Special precautions required.
¶ Many of these materials are suitable for resisting dry corrosion at elevated temperatures.

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Source: Perry and Chilton, Ed., Chemical Engineers' Handbook, 5th Ed., McGraw-Hill Co., New York, 1973.

- limited corrosion resistance to certain wastes; therefore, extra thickness for corrosion allowances is often needed beyond the minimum thickness required for structural integrity when no lining or coating is used

- should not be used on contact with hydrochloric, phosphoric, or nitric acid

(b) Alloy steels. Stainless steel is the most widely used alloy steel. At high temperatures it is highly resistant to corrosion and oxidation while maintaining considerable strength.

The following is a list of the types of alloy (stainless) steels and their characteristics:

- austenitic steel
  - is the most highly resistant of stainless steels to many acids, including hot or cold nitric acid
  - retains strength at temperatures as low as liquid helium
  - responds well to severe stress at elevated temperatures
- martensitic steel
  - is less corrosion resistant than austenitic steel
  - used for mildly corrosive environments such as organic exposures
- ferritic steel
  - has good corrosion resistance

(2) Concrete. This material is predominantly used in large open tanks and treatment basins. Several characteristics of concrete are listed below:

- susceptible to freeze-thaw cracking and deterioration if not properly air entrained
- subject to attack by copper and ferric sulfates if not made with sulfate-resistant cement
- subject to attack by certain chemicals including alum, chlorine, ferric chloride, sodium bisulfite, sulfuric acid, and sodium hydroxide (<20 percent).

The permit writer must ascertain the effect of the waste proposed for storage upon the tank construction materials and the liner materials (if present). For further discussion of compatibility between the waste proposed for storage and the tank materials, refer to:

- Compatibility of Wastes in Hazardous Waste Management Facilitites: A Technical Resource Document.[2]
- manufacturers' literature regarding chemical and physical properties of tank and liner materials
- Perry's Chemical Engineers' Handbook, which contains specific sections on corrosion[11]
- literature published by the National Association of Corrosion Engineers in Houston, Texas[12, 13]
- information published by the American Concrete Institute[14]

(3) Lining and Coating Material. Tank deterioration, as a result of waste and tank material incompatibility, may cause tank failure. In situations where the waste is corrosive to the material of construction of the tank, some type of protection may be required. Both linings and coating materials are often used to protect the construction materials of a tank. The permit writer should review the waste type and tank materials of construction to assure that the tank is protected against corrosion. Linings and coatings are defined below.

- "Linings" are sheet materials attached to the inner shell of a tank. Common lining materials include rubber, plastic, tar, lead, and brick.
- "Coatings" are thin films and natural or synthetic organic material, either sprayed or brushed on the inside surface of the tank to reduce internal/external deterioration.

The following discussion presents the more common lining and coating materials. (Refer to the National Association of Corrosion Engineers for further information.[13])

(a) Plastics.[11] In general, plastics have the following characteristics:

- have excellent resistance to weak mineral acids and inorganic salt solutions
- have good electrical and thermal insulators

- do not corrode from chemical reactions

- do not react to small changes in pH, minor impurities, or oxygen content

The most widely used plastics for coating and lining materials include: polyethylene, chlorinated polyether, cellulose acetate butyrate, polyamide, polypropylene, polyester resin, and epoxy.

- Polyethylene is the least costly plastic that is commercially available. The carbon-filled grades are resistant to sunlight and weathering.

- Chlorinated polyether (Penton) can withstand temperatures up to 255°F. It is not affected by dilute acids, alkalies, or salts. However, nitric acid over 25 percent in concentration, aromatics, and ketones cause degradation.

- Cellulose acetate butyrate is affected by chlorinated solvents, but not by dilute acids or alkalies.

- Polyamide (nylon) resists a number of organic solvents, but is not resistant to phenols, strong oxidizing agents, or mineral acids.

- Polypropylene has characteristics similar to those of polyethylene, and it can be used at temperatures greater than 250°F.

- General-purpose polyester resins, when reinforced with fiberglass, have good strength and good chemical resistance, except to alkalies. Polyesters containing bisphenol are more alkali resistant. The temperature limit for using polyesters is about 200°F.

- Epoxy has good chemical resistance to nonoxidizing and weak acids. It is also resistant to weak alkaline solutions.

(b) Rubber.[11] Rubber and elastomers are frequently used as coating and lining materials. In addition to natural rubber, a number of synthetic rubbers have been developed. While none have all the properties of natural rubber, some are superior for specific uses.

Natural rubber is resistant to dilute mineral acids, alkalies, and salts, but not to oxidizing agents, oils, benzene, and ketones. Hard rubber is made by adding 25 percent or more sulfur to natural or synthetic rubber, thus making it both hard and strong.

- Chloroprene or neoprene rubber is resistant to attack by ozone, sunlight, oils, gasoline, and aromatic or halogenated solvents.
- Styrene rubber has chemical resistance similar to natural rubber.
- Nitrile rubber is resistant to oils and solvents.
- Butyl rubber's resistance to dilute mineral acids and alkalies is exceptional; its resistance to concentrated acids, except nitric and sulfuric, is good.
- Silicone rubbers, also known as polysioxanes, have outstanding resistance to high and low temperatures and to aliphatic solvents, oils, and greases.
- Chlorosulfonated polyethylene, known as hypalon, has outstanding resistance to most ozone and oxidizing agents except fuming nitric and sulfuric acids. Its oil resistance is good.
- Fluroelastomer (Viton A, Kel-F) combines excellent chemical and high-temperature resistance.
- Polyvinyl chloride elastomer (Koroseal) was developed to overcome some of the limitations of natural and synthetic rubbers. It has excellent resistance to mineral acids and petroleum oils.
- The cis-polybutadiene and cis-polyisoprene rubbers are almost duplicates of natural rubber.
- The newer ethylene-propylene rubbers have excellent resistance to heat and oxidation.

Table 3-3 lists the properties and chemical resistance of many organic coatings; Table 3-4 summarizes the chemical resistance of rubber materials. Compatibility evaluation may be made based on information in these tables.

(c) Gaskets. Gaskets serve as fillers in static clearances that usually occur at concentric cylinders. Sealing is achieved by subjecting effective compression through bolts or other mechanical means. Improper gasket installation can easily result in a leak. Therefore, extra care should be given to select the proper type of gasket as well as the proper material of construction and to ensure quality control during installation.

The most common types of gaskets are cylindrical or concentric, o-ring joints, and valve seats. Gasket selection should be based on site-specific objectives. During installation, care

TABLE 3-3

Properties and Chemical Resistency of Organic Coatings[a]

	Alkyd						Acrylic	Bituminous	Cellulose			Epoxy					
	Alkyd	Alkyd-amine	Alkyd-phenolic	Alkyd-silicone	Alkyd-urea	Styrenated alkyd	Acrylic	Bituminous	Nitrocellulose	Butyrate	Ethyl cellulose	Epoxy-amine	Epoxy-ester	Epoxy-furane	Epoxy-melamine	Epoxy phenolic	Epoxy-urea
Chemical resistance:																	
Exterior durability	E	E	E	E	E	F	E	E	E	E	E	G	E	E	E	E	VG
Salt spray	E	VG	E	E	G	G	E	E	E	E	......E......	VG	E	E	E	E	E
Solvents, alcohols	G	G	G	G	G	G	F	P	G	G	F	G	F	E	E	E	E
Solvents, gasoline	E	E	E	E	E	E	G	P	G	G	F	E	E	E	E	E	E
Solvents, hydrocarbons	G	E	E	G	E	E	F	P	F	F	F	E	VG	E	E	E	E
Solvents, esters, ketones	P	F	F	F	F	F	F	P	P	P	P	VG	F	E	VG	E	VG
Solvents, chlorinated	P	F	F	F	F	F	F	P	P	P	P	G	F	G	E	E	E
Beverages, food	P	G	VG	G	G	VG	VG	P	G	G	E	E	VG	E	E	E	E
Salts	VG	E	E	VG	E	E	VG	G	G	VG	G	E	F	E	E	E	E
Ammonia	F	F	F	F	F	F	F	......E......	F	F	G	G	F	E	F	F	F
Alkalis[b]	F, P	VG, G	F, P	VG, G	G, G	G, VG	G, F	G, —, —	F, P	F, P	G, G	E, E	E, E	E	F, E	F, E	E, E
Acids, mineral[c]	P, P, P	G, F, P	VG, G, F	G, F, P	F, P, P	G, F, P	G, F, P	E, ...—, —	E, G, F	G, F, P	G, F, P	E, VG, G	G, F, P	G	E, VG, G	E, F, E	E, VG, F
Acids, oxidizing[c]	P, P, P	F, P, P	G, F, P	F, P, P	F, P, P	F, P, P	F, P, P	P	F, P, P	F, P, P	F, P, P	G, F, P	F, P, P	F	G, F, P	E, VG, F	F, P, P
Acids, organic (acetic, formic, etc.)[c]	P, P, P	F, P, P	F, P, P	F, P, P	F, P, P	F, P, P	F, P, P	P	F, P, P	F, P, P	E, —, —	F, F, P	F, P, P	F, G	G, F, P	E, E, VG	F, P, P
Acids, organic (oleic, stearic, etc.)	P	G	VG	G	P	P	P	P	P	P	......	F	E	E	E	E	E
Acid, phosphoric	P	F	F	F	P	P	P	E	F	P	......E......	G	P	E	G	E	G
Water (salt, fresh)	P	G	G	G	P	G	E	E	G	E		G	VG	E	G	E	G
Physical properties:																	
Sward rocker hard. (8th day)	24	20	34	16–20	20	25	24	......	20	26	25–30	36	20	24	36	44	34
Flexibility	E	VG	G	VG	VG	G	E	......E......	E	E	E	F	E	E	VG	VG, E	VG
Abrasion resistance, cycles[d]	3500	>5000	>5000	4000	>5000	>5000	2500	......	2500	2500	......	>5000	>5000	......	>5000	>5000	>5000
Max. oper. temp., °F	200	250	250	450	225	200	180	200	180	180	200	400	300	350	400	400	400
Toxicity	None	Slight	None	None	Slight	Slight	None	......	None	None	None	None	None	None	None	None	None
Impact resistance	VG	E	G	G	E	G	E	......E......	E	E	E	G	E	G	VG	VG	G
Dielec. properties	G	G	VG	E	G	G	VG	......	P	G	E	VG	VG	G	VG	VG	VG
Adhesion to:																	
Ferrous metals	E	E	E	VG	E	F	VG	E	VG	VG	P	E	E	E	E	E	E
Nonferrous metals	F	E	E	VG	VG	F	VG	E	G	G	P	E	E	E	E	E	E
Old paints	VG	G	G	E	G	VG	F	......	P	P	P	G	VG	E	F	F	F

[a] These data are intended only as a preliminary selection guide. Final selections should be made after consulting with coating formulator.

Key: E = excellent; VG = very good; G = good; F = fair; P = poor.

[b] Two ratings are for dilute (20%) and concentrated, respectively.

[c] Three ratings are for dilute (10%), medium (10–30%), and concentrated, respectively.

[d] Taber CS-10 wheel.

[e] Not recommended with nitric acid.

[f] Not recommended with strong acetic acid solutions.

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Source: Chemical Engineers' Handbook, 5th ed., Robert H. Perry and Cecil H. Chilton (New York: McGraw-Hill, 1973). Used by permission of McGraw-Hill Book Company.

TABLE 3-3

Properties and Chemical Resistance of Organic Coatings[a]—(Concluded)

	Chlorinated polyether	Chlorinated polypropylene	Fluorocarbon (air-dried)	Furane	Phenolic	Polyamide (nylon)	Polyester	Polyethylene	Rubber				Silicone	Urethane	Vinyl	Vinyl-alkyd (approx. 1:1)
									Chlorinated rubber	Neoprene	Hypalon	Viton				
Chemical resistance:																
Exterior durability	E	E	E	G	E	F	E	P	E	E	E	E	E	E	E	E
Salt spray	E	E	E	G	E	F	E	VG	E	E	E	E	E	E	E	E
Solvents, alcohols	E	G	E	E	E	G	G	E	E	E	....	E	F	F–E	E	G
Solvents, gasoline	E	G	E	E	E	G	E	F	G	F	F	E	VG	F–G	G	E
Solvents, hydrocarbons	E	P	E	E	E	....	E	F	F	G	....	E	F	F–E	G	F
Solvents, esters, ketones	E	P	F	G	F	....	F	G	F	F	F	F	F	F	F	F
Solvents, chlorinated	E	P	E	E	F	....	F	F	F	F	F	G	F	F–E	F	F
Beverages, food	E	G	E	E	E	....	G	E	G	E	F	E	G	VG	E	F
Salts	E	E	E	E	E	....	G	E	E	E	E	E	F	E	E	G
Ammonia	E	G	E	E	F	G	F	E	G	E	F	E	F	F	E	F
Alkalis[b]	E	VG, VG	E, E	E	F, F	G, G	F	F, G	E, E	E, E	E, F	E, E	E, F	VG, F	E, E	G, F
Acids, mineral[c]	E, E, E	E, G, G	E, E, E	G	G, F, F	F, F, F	E	....	E, E, G	E, G, F	E, E, E	E, E, E	G, G, F	G, F, F	E, E, G	VG, G, F
Acids, oxidizing[c]	E, E, E	E, E, G	E, E, E	P	G, F, F	....	F	VG, VG, VG	E, E, F	F, F, F	G, F, F	G, F, E	F, F, F	G, F, F	E, VG, G	F, F, F
Acids, organic (acetic, formic, etc.)[c]	E, E, E	G, F, F	E, E, E	F, G	G, F, F	F, F, F	F	VG, F, F	G, F, F	F, F, F	F, F, F	E, E, E	F, F, F	G, F, F	E, F, F	G, F, F
Acids, organic (oleic, stearic, etc.)	E	G	E	E	E	VG	F	G	F	F	F	E	G	E	E	E
Acid, phosphoric	E	G	E	E	F	....	F	VG	G	VG	E	E	F	E	E	F
Water (salt, fresh)	E	E	E	E	E	F	G	E	E	E	E	E	E	E	E	E
Physical properties:																
Sward rocker hard. (4th day)	....	21	<10	20	30	....	30	....	21	<10	<10	<10	16	35–65	20	26
Flexibility	F	VG	G	F	G	G	G	E	VG	E	E	G	F	E	E	E
Abrasion resistance, cycles[d]	>5000	3000	1000	....	>5000	....	3500	....	>5000	5000	3000	1000	2500	>5000	>5000	2500
Max. svc. temp., °F	300	250	550	300	350	300	200	225	200	200	250	550	550	300	150	180
Toxicity	None	Slight	Slight	None	None	....	None	None	Slight	None	....	Slight	None	Slight	None	None
Impact resistance	F	G	E	F	G	VG	F	E	G	E	E	E	F	E	E	E
Dielec. properties	E	E	E	F	E	G	G	E	E	F	VG	E	E	E	E	G
Adhesion to:																
Ferrous metals	VG	G	VG	F	E	VG	F	E	F	VG	VG	VG	F	E	G	VG
Non-ferrous metals	G	VG	VG	F	E	VG	F-F	E	VG	VG	VG	VG	E	E	VG	G
Old paints	P	E	P	E	G	....	P	P	F	....	F	P	E	G	F	P

Source: Perry and Chilton, Ed., Chemical Engineers' Handbook, 5th Ed., McGraw-Hill Co., New York, 1973.

TABLE 3-4

CHEMICAL RESISTANCE OF RUBBER MATERIALS [11]

Type of Rubber	Features
Butadiene-styrene	General-purpose; poor resistance to hydrocarbons, oils, and oxidizing agents
Butyl	General-purpose; relatively impermeable to air; poor resistance to hydrocarbons and oils
Chloroprene	Good resistance to aliphatic solvents; poor resistance to aromatic hydrocarbons and many fuels
Chlorosulfonated polyethylene	Excellent resistance to oxidation, chemicals, and heat; poor resistance to aromatic oils and most fuels
cis-Polybutadiene . .	General-purpose; poor resistance to hydrocarbons, oils, and oxidizing agents
cis-Polyisoprene . . .	General-purpose; poor resistance to hydrocarbons, oils, and oxidizing agents
Ethylene-propylene . .	Excellent resistance to heat and oxidation
Fluorinated	Excellent resistance to high temperature, oxidizing acids, and oxidation; good resistance to fuels containing up to 30% aromatics
Natural	General-purpose; poor resistance to hydrocarbons, oils, and oxidizing agents
Nitrile (butadiene-acrylonitrile) . . .	Excellent resistance to oils, but not resistant to strong oxidizing agents; resistance to oils is proportional to the acrylonitrile content
Polysulfide	Good resistance to aromatic solvents; unusually high impermeability to gases; poor compression set and poor resistance to oxidizing acids
Silicone	Excellent resistance over unusually wide temperature range (-150 to +500°F.); fair oil resistance; poor resistance to aromatic oils, fuels, high-pressure steam, and abrasion
Styrene	Synonymous with butadiene-styrene

Source: Chemical Engineers' Handbook, 5th ed., Robert H. Perry and Cecil H. Chilton (New York: McGraw-Hill, 1973). Used by permission of McGraw-Hill Book Company.

should be taken so that the gasket is properly placed in the flange and that it is not excessively compressed beyond the material's elastic limit. It should be noted that proper materials selection is imperative to avoid gasket deterioration, as a result of incompatibility between hazardous materials stored in the tank and the material of construction of the gasket.

Proper maintenance of gaskets will enhance the life and maximize performance. It is imperative that the manufacturers' recommendations for installation as well as maintenance be followed. In some cases, if deterioration is detected, the gasket should be immediately replaced.[15]

(d) Selection. Whether to use a liner or coating material or utilize extra metal thickness to provide for tank corrosion allowance is an engineering decision.[16] Factors to consider include:

- type of waste stored
- construction material used for structural support
- availability of material
- ease of application

b. Minimum Thickness and Corrosion Allowances. The following section considers minimum wall thickness and corrosion allowance as they interact with the expected service life of a tank.

All tanks must have a minimum wall thickness to provide structural integrity and thus prevent the collapse of the tank. Design standards for tanks specify a minimum thickness for the tank shell. The specified minimum thickness includes a small allowance for corrosion and unexpected stresses owing to pressure changes. On the basis of applicable design standards or other engineering information, the permit writer will specify a minimum thickness for the tank in the facility's permit. The owner or operator is expected to maintain this minimum thickness throughout the service life of the tank.

The difference between the actual thickness of the tank wall and the minimum required thickness (as specified in the design standard of the facility's permit) is frequently referred to as the corrosion allowance.

(1) Minimum Wall Thickness. Minimum wall thickness is specified in the design standard or the facility's permit. The minimum wall thickness is normally slightly greater than necessary to provide structural support under normal conditions and to allow for small amounts of corrosion or erosion or extraordinary stresses. Since pressures on the tank wall are greater at the bottom, different thicknesses might be specified for upper and lower portions of the tank shell. Inspection procedures for measuring wall thickness are required by the regulations.

Minimum thickness is normally calculated on the basis of a formula specified by each standard code. The components of the formula include: specific gravity of contents, height of liquid in tank, and diameter of tank.

The following are commonly used design and construction codes for tanks.*

Atmospheric Pressure Tanks

- Underwriters' Laboratories, Inc., No. 142,[8] Standard for Steel Aboveground Tanks for Flammable and Combustible Liquids, 1972
- Underwriters' Laboratories, Inc., No. 58, Standard for Steel Underground Tanks for Flammable and Combustible Liquids, Fifth Edition, December 1961
- American Petroleum Institute (API) Standard No. 12A, Specification for Oil Storage Tanks with Riveted Shells, Seventh Edition, September 1951;
- API Standard No. 12B, Specification for Bolted Production Tanks Eleventh Edition, May 1958, and Supplement 1, March 1962
- API Standard No. 12D, Specification for Large Welded Production Tanks, Fifth Edition, March 1961
- API Standard No. 650[3] Welded Steel Tanks for Oil Storage, Sixth Edition, 1979

Low-Pressure Tanks

- API Standard No. 620,[4] Recommended Rules for the Design and Construction of Large, Welded, Low-Pressure Storage Tanks, Fifth Edition, 1973

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* When tanks are not designed in accordance with American Petroleum Institute, American Society of Mechanical Engineers, Underwriters' Laboratories, or American Concrete Institute standards, the stress on the tank must be calculated directly and a margin of safety allowed in establishing minimum thickness. If significant corrosion is anticipated, additional thickness of the metal or suitable protective coatings or linings should be provided to compensate for the loss from corrosion expected during the life of the tank.

- Code for Unfired Pressure Vessels, Section VIII of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessels Code,[6] 1974

High-Pressure Tanks

- Section VIII of the ASME Boiler and Pressure Vessels Code,[6] 1974

Concrete Tanks

- American Concrete Institute, publication ACI-350R-77, Concrete Sanitary Engineering Structures[9]

Fiberglass Tanks

- Section X of the ASME Boiler and Pressure Vessels Code, 1974

(2) Corrosion Allowance. Corrosion alowance is defined as the difference between the actual thickness of a tank's walls at a given time* and the required minimum thickness of the tank wall. Actual thickness of tank walls varies. A pit or very small corroded area does not weaken the shell plate appreciably from the standpoint of resisting pressure. A good rule to follow in establishing a plate thickness for a corroded area** is that the average thickness over a distance in longitudinal direction is equal to 16 times the minimum allowable thickness. This average should be used for comparison with the minimum thickness. Because corrosion is a continuous process, the corrosion allowance diminishes over time.

c. Expected Service Life. Expected service life is defined as the corrosion allowance divided by the corrosion rate of the waste upon the construction materials of the tank. The expected life is the amount of time that a hazardous waste can be stored in a tank before the corrosive action of the waste causes the thickness of the tank walls to equal the minimum required thickness. Information on the expected service life is valuable in determining frequency of inspection and renewal dates for permits.

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* Measures of wall thickness should be exclusive of the thickness of any coatings or linings applied to the tank walls. However, use of coatings or linings to protect and maintain wall thickness is encouraged in many cases.

** From American Petroleum Institute, Guide for Inspection of Refinery Equipment, Chapter XIII, 3rd Edition, p.43. Use of alternative methods for measuring shell thickness should be justified by the permit applicant.

Since hazardous wastes are usually mixtures of chemicals, the corrosion rates of materials exposed to them might not be absolutely known. The National Association of Corrosion Engineers (NACE)[12, 13] and Perry[11] have published data on corrosion rates for different materials. Representative tables and a discussion of their use are contained in the permit writers' guide on hazardous waste compatibility.[2] These tables can be used to estimate the corrosion rates of materials if the chemicals stored have similar properties. If the properties of the major component of the hazardous waste can be assumed to have dominating influence on the properties of the waste, the corrosion rate may also be assumed (conservatively) to be the same as that for the pure chemical. The actual corrosion rate must be measured thereafter through periodic inspection. (Caution should be exercised in relying upon published corrosion rates since such factors as the oxygen and water content and the chlorine content and temperature of the waste can significantly affect the corrosion rate causing substantial variation from the published value.)

If a particular waste and the construction materials of the tank are incompatible (very high corrosion rate), the tank should not be used to store that waste.

In order to estimate the expected service life of a tank, the permit writer should determine:

- the standard code used for building the tank;
- the materials used for construction and their properties;
- the required minimum thickness of the shell plates of a tank, which is a function of the contained liquid's specific gravity, height of liquid level, and diameter of the tank;
- the corrosion allowance;
- the presumed initial corrosion rate or the actual corrosion rate based on periodic measurements.

d. Examples. Three examples have been developed to illustrate the interdependency of the factors involved in determining the expected service life of a tank. These examples illustrate how the minimum required tank wall thickness, the corrosion allowance, and the expected service life are determined. Various interactions (trade-offs) among minimum required thickness, corrosion allowance, and expected life are also presented.

(1) Example 1. A vertical, cylindrical, welded carbon steel tank built in 1974 and used for the storage of oil is to be converted to store hazardous waste at a maximum design pressure equal to 0 psig (atmospheric pressure) and at ambient

temperature. The tank, which has 72-inch butt-welded courses, was built in accordance with the second edition of API Standard 650. The tank is 60 feet in diameter and 30 feet high. The oil-specific gravity is less than 1.0, and the shell plate thickness was measured to be 0.76 inch uniformly prior to the tank's being converted to store the waste. API Standard 650 specifies the following formula in calculating the minimum thickness of the tank's walls to preclude excessive stresses:

$$t = \frac{(2.6)\ (D)\ (H-1)\ (G)}{(0.85)\ (21000)}$$

t = minimum tall thickness, in inches

D = nominal diameter of tank, in feet

H = height, in feet, from bottom of course under consideration to overflow that limits tank filling or to overfilling alarm or feed cutoff trigger

g = specific gravity of liquid to be stored, but in no case less than 1.0

0.85 = joint efficiency factor

21000 = maximum allowable tensile strength for applying the factor for efficiency of joint

$$t = \frac{(2.6)\ (60)\ (30-1)\ (1.0)}{(0.85)\ \ (21000)}$$

$$= 0.25 \text{ inch (approx.)}$$

As calculated above, this tank requires a minimum wall thickness of 0.25 inches to accommodate the stresses presented by oil stored in this tank to a height of 30 feet. If the tank were to be used to store hazardous waste with a specific gravity less than or equal to 1.0 and a height of 30 feet, the initial corrosion allowance would be 1/2 inch (0.76 inches - 0.25 inches = 0.51 inches).

The hazardous waste to be introduced into this tank, however, was measured to have a specific gravity of 1.2, and the owner or operator has decided to keep the minimum wall thickness of 0.25 inch in order to have the maximum 0.51 inches of corrosion allowance to prolong the service life of the tank. Since the specific gravity of the waste will place greater stress on the tank's walls, the maximum height allowed for storing the waste is calculated to be:

$$0.25 = \frac{(2.6)\ (60)\ (H-1)\ (1.2)}{(0.85)\ \ (21000)}$$

$$H = 24 \text{ feet (approx.)}$$

The tank in this case can only have a minimum waste liquid level of 24 feet if the maximum allowable stress is not to be exceeded. Overfilling controls should be established at this level.

We assume that the hazardous waste is a salt solution contaminated by heavy metals with the major component being ferrous sulfate. Utilizing the National Association of Corrosion Engineers (NACE)[12] table, we find that ferrous sulfate has a corrosion rate of greater than 0.05 inch per year on carbon steel. Assuming conservatively that the waste has a corrosion rate of 0.1 inches per year, we determine that the expected service life of this tank for storing this waste is calculated to be 5.1 years (0.51 inch divided by 0.1 inch per year = 5.1 years). Therefore, theoretically this tank should be used to store this particular waste for no more than 5.1 years at a height not to exceed 24 feet. It should be noted, however, that a corrosion rate of greater than .05 inches per year is extremely high. In most cases, a liner would be used if ferrous sulfate were to be stored in a carbon steel tank. After an initial storage period, the actual corrosion rate should be physically measured, and by knowing the corrosion allowance and this actual corrosion rate, we can determine the expected life of a tank. The owner-operator should be required to measure the actual corrosion rate as part of the periodic assessment of the tank's condition within a given period and report it to the permit writer when renewing the permit.

As the tank approaches the end of its expected life, the owner-operator should increase the frequency of comprehensive inspections of the tank and be prepared to recoat or reline the tank; derate the tank (which means that the liquid level can be lowered to reduce the stress and, therefore, reduce the required minimum wall thickness, and increase the corrosion allowance); introduce a new waste with lower specific gravity to reduce the stress; or prepare the tank for closure.

(2) Example 2. An above-ground, horizontal, cylindrical welded steel tank, built in 1973 and used for the storage of gasoline, is to be converted for the temporary storage of slightly

corrosive waste at ambient temperature and at a maximum internal pressure of 0.5 psig. The tank was built according to the fourth edition of Underwriters' Laboratory (UL) Standard 142 and installed in accordance with the Flammable and Combustible Liquids Code of the National Fire Protection Association (NFPA No. 30). The tank is 144 inches in diameter and has a uniform measured shell thickness of 3/8 inch and a maximum capacity of 35,000 U.S. gallons. The hazardous waste to be stored has a specific gravity of less than 1.0 and a theoretical corrosion rate of 0.05 inch per year on the construction material of the tank.

The owner would like to store from 1,000 to 30,000 gallons of waste in the tank at a given time. The following tabulation from UL 142 indicates that a minimum thickness of 0.25 inch must be maintained to provide for structural stability to accommodate the upper volume limit of 30,000 gallons:

METAL THICKNESS - HORIZONTAL TANKS

Capacity U.S. Gallons	Maximum Diameter, Inches	Minimum Thickness of Steel, Inches
550 or less	48	0.105
551 - 1,100	64	0.135
1,101 - 9,000	76	0.179
1,101 - 35,000	144	0.250
35,001 - 50,000	144	0.375

The tank, therefore, has a maximum corrosion allowance of 0.125 inch, which is 3/8 inch (current actual thickness) minus 1/4 inch (allowable minimum thickness). If the waste to be stored has a corrosion rate of 0.05 inch per year, the expected life of the tank storing 30,000 gallons of waste is 2 1/2 years ((0.125 inch divided by 0.05 inch per year) prior to coating, lining, or closing the tank. Even if the tank were to be utilized to store a maximum of 1,000 gallons, however, the tank could still only be used for a period of 2 1/2 years (0.375 minus 0.250 inch divided by 0.05 inch per year) because a tank that is 144 inches in diameter must have 0.25 inch minimum wall thickness, according to this standard.

(3) Example 3. A vertical, cylindrical welded carbon steel tank is to be converted to storage of hazardous waste at a maximum design pressure equal to 0 psig (atmospheric pressure) and of ambient temperature. The tank was built in accordance with the

second edition of API Standard 650. The tank is 55 feet in diameter and 25 feet high. The specific gravity of the waste to be stored in the tank was measured to be 1.2. Therefore, the minimum wall thickness in inches is:

$$t = \frac{(2.6)\ (55)\ (24)\ (1.2)}{(.85)\ (21000)}\ ^{*}$$

$$t = 0.23 \text{ inches}$$

The wall thickness of the tank is nonuniformly corroded. The thickness was measured in 30 locations, and the results are given below:

1) 0.20
2) 0.19
3) 0.22
4) 0.24
5) 0.22
6) 0.20
7) 0.18
8) 0.23
9) 0.16
10) 0.20
11) 0.21
12) 0.19
13) 0.17
14) 0.17
15) 0.18
16) 0.23
17) 0.20
18) 0.22
19) 0.14
20) 0.23
21) 0.21
22) 0.20
23) 0.21
24) 0.24
25) 0.21
26) 0.19
27) 0.21
28) 0.24
29) 0.19
30) 0.19

At points 9, 13, 14, and 19, 5 additional measures were made along a longitudinal strip 4 inches long. The average measured thicknesses at these points were as follows:

9) .16
13) .18
14) .19
19) .16

The minimum of these local averages is used for comparison with the required minimum thickness.

Since the measured thickness is less than the required minimum thickness, the tank must be derated or removed from service. If it is assumed that the owner-operator decided to derate the tank, the new high level would be calculated as follows:

$$t = \frac{(2.6 \times H-1\ (55)\ (1.2)}{(.85)\ (21000)}$$

H = 17.6
rounding down
H = 17

The owner-operator would install overfilling controls (e.g., high-level alarms or automatic feed cutoff) at 17 feet. In addition, since no corrosion allowance remains, the owner-operator should coat or line the tank to prevent further loss of their thickness.

---

* Formula from Example 1.

e. Decision Process. The minimum thickness of a tank shell can be maintained by designing the tank with extra shell thickness (corrosion allowance) or by lining or coating the tank. The owner-operator must decide how the shell thickness will be maintained when the tank is built or converted to store hazardous waste. No specific guidance can be given on this decision. The following example illustrates the decision-making process that an owner-operator may undergo when converting an existing storage tank to use as a hazardous waste storage tank.

When the tank was built, one of the following was the case:

(1) Extra metal thickness was provided as a corrosion allowance. If so,

   (a) the tank may have to be derated, meaning the liquid level has to be lowered in order not to exceed the maximum allowable stress;

   (b) the tank may be used to store a hazardous waste that is relatively noncorrosive with the tank's material of construction so that the corrosion allowance is not exceeded;

   (c) lining material may have to be added;

   (d) coating material may have to be added.

(2) An interior lining or coating material was provided when the tank was first constructed. If so, the tank needs to be examined to determine whether the lining or coating is in good condition. If there are leaks, cracks, holes, or other deterioration, the tank should be relined or recoated. The procedure used to calculate the minimum required thickness of metal must be followed to determine if the tank is structurally sound in its present condition.

C. ANCILLARY DESIGN FEATURES FOR SAFE OPERATION

1. Measurement Devices

Process variables need to be measured and maintained routinely at certain values. These variables are monitored by electrical, mechanical, or chemical devices. Control devices may serve this purpose. The following measures should be taken regularly to ensure safe operation of a tank facility. The permit writer should determine whether or not procedures needed to measure these variables are adequate.

a. Temperature of waste. Abnormal temperatures may indicate that undesired reactions are occurring in the tank, excessive heat is being generated, hazardous vapors are being emitted, etc.

b. Pressure. Measure to ensure that design pressure of a tank is not being exceeded.

c. Flow. Measure to preclude overfilling of a tank, etc.

d. Level. Measure to preclude overfilling, maintain desired liquid level.

e. Specific Gravity. Measure to ensure that weight of liquid does not place excessive stress upon the tank.

Refer to Perry's Chemical Engineers' Handbook, Chapter 22, for a description of measurement devices.[11]

2. Overfilling Control Systems

40 CFR 264.192 states that tanks must be equipped with overfilling control systems. The two most important components of overfilling control, flow measurement, and level measurement, are discussed below.[17]

a. Flow Measurement. Monitoring of the flow rate into the tank can be used in continuous flow systems to prevent overfilling or pressure buildup owing to an increase in the in-flow rate. Flow rate measurements alone are, however, insufficient to prevent overfilling. A complete overfilling control system for a continuous flow tank should also include at least one of the following:

(1) an alarm triggered by excessive flow rate and an accessible feed cutoff valve;

(2) a by-pass line to a standby tank; or

(3) a feed cutoff system or alarm triggered by a liquid level measurement device as described in the following section.

The major types of flow measurement devices are described below:

(a) Local static pressure. The pressure on the surface of the pipe is measured by making a small hole perpendicular to the surface and connecting the opening to a pressure-sensing element.

(b) Velocity meters. Pitot tubes measure local velocities by measuring the difference between impact pressure and static pressure.

(c) Pressure meters. The rate of flow through the pipe is calculated from the pressure drop caused by the constriction.

(d) Mass flowmeters. The mass flow rate can be measured directly by creating angular momentum with an impeller and then measuring the torque this momentum imparts to a turbine; or the volumetric flow rate can be measured and the mass flow rate calculated using fluid density.

b. Liquid-Level Measurement and Control.[11] The most effective means of preventing overfilling in a tank is through the use of a liquid level measurement device connected to an alarm or automatic feed cutoff system. Several types of liquid level measurement devices are discussed below, any of which could be used to control a switch for an alarm or feed cutoff valve.

(1) Float-Activated Devices

Float-activated devices are characterized by a float on the surface of a liquid. A level sensing electrical switch based on a magnetic float-activated device is illustrated in Figure 3-1.

(2) Displacer Device

Displacer-activated level measuring is accomplished through measurement of the buoyant force on a partially submerged float. The force on the displacer (i.e., float) can be determined by measuring compression of a spring that holds the displacer in place or through measurement of the force on a torque tube connected to the displacer by a rod. The range of a displacer device is limited to the length of the displacer.

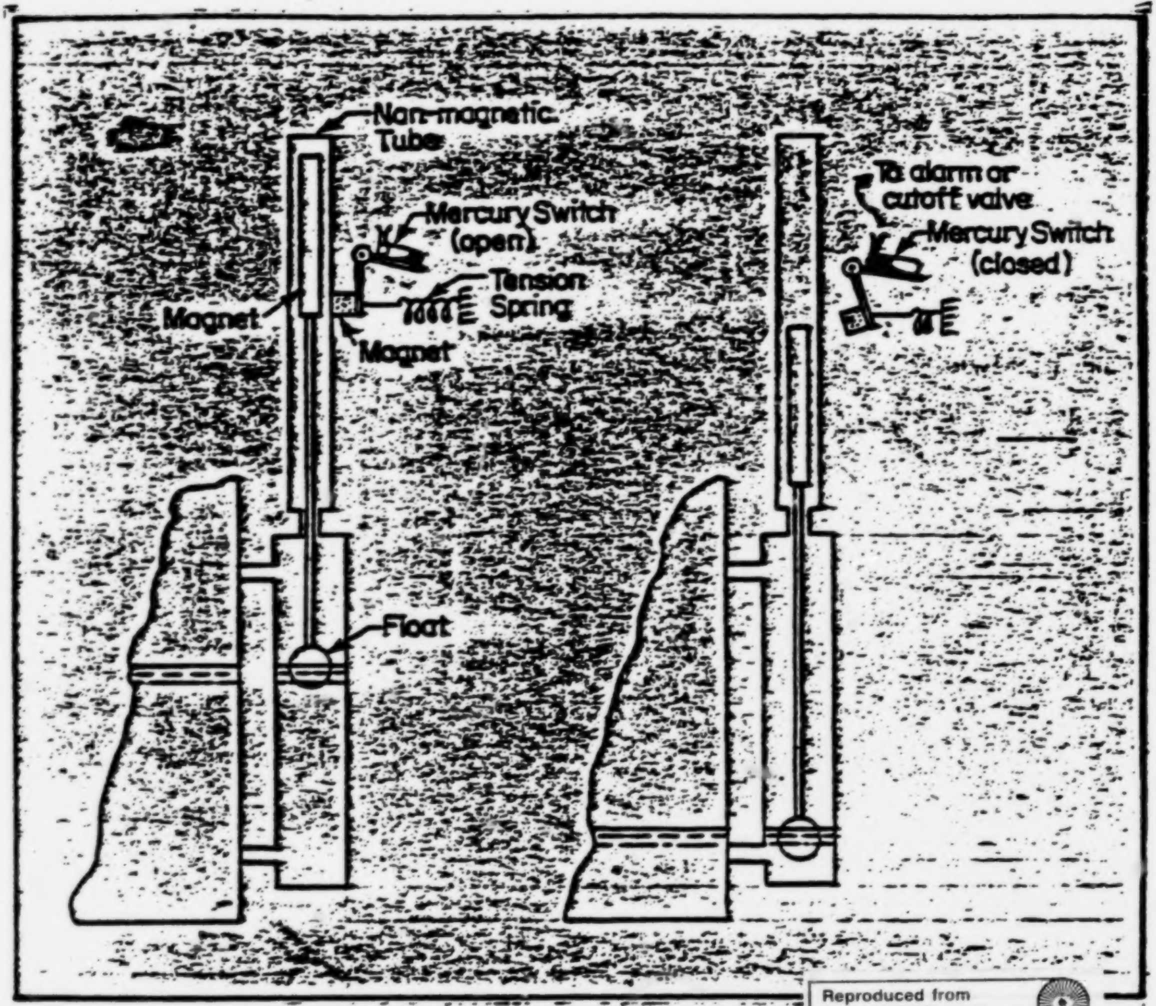
(3) Head Device

A variety of devices utilize hydrostatic head as a measure of level. The majority of these devices utilize standard pressure and differential pressure measuring devices. Figure 3-2 illustrates a simple hydrostatic head device in which a constant air flow is used to prevent entry of the process liquid into the measuring system.

c. Freeboard. In addition to overfilling controls, owners-operators of open tanks are required to maintain sufficient freeboard to prevent overtopping owing to wind or wave action or precipitation.[17] In a tank of less than 100 meters in diameter the maximum height of a wind-induced wave is 4 to 5 inches.[18] Allowing another 4 to 5 inches for splashing on the sides and precipitation, 8 to 10 inches of freeboard is adequate for most tanks.

FIGURE 3-1

FLOAT-ACTIVATED LEVEL SENSING SWITCH

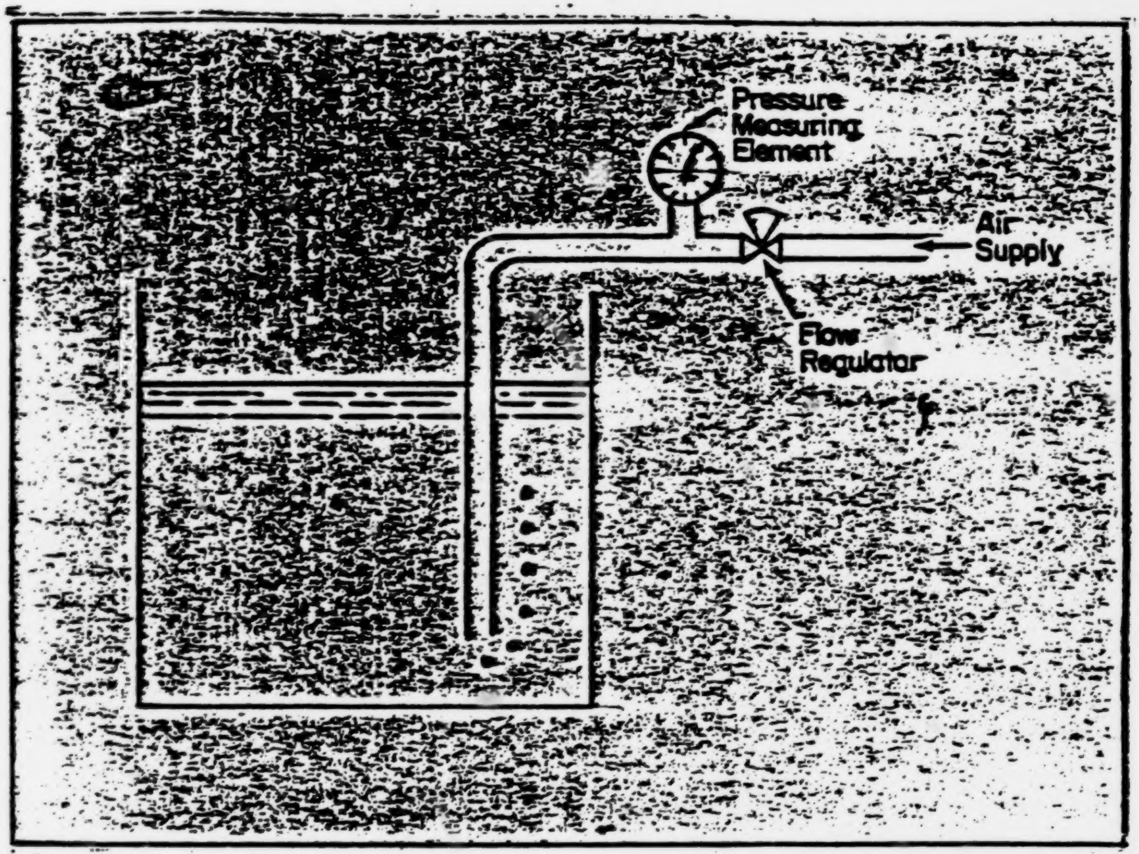

Non-magnetic Tube
Mercury Switch (open)
Tension Spring
Magnet
Magnet
Float
To alarm or cutoff valve
Mercury Switch (closed)

Reproduced from best available copy.

Source: Chemical Engineers' Handbook, 5th ed., Robert H. Perry and Cecil H. Chilton (New York: McGraw-Hill, 1973). Copyright 1973. Used by permission of McGraw-Hill Book Company.

FIGURE 3-2

HEAD DEVICE FOR LIQUID LEVEL MEASUREMENT


Pressure Measuring Element
Air Supply
Flow Regulator

Source: Chemical Engineers' Handbook, 5th ed., Robert H. Perry and Cecil H. Chilton (New York: McGraw-Hill, 1973). Copyright 1973. Used by permission of McGraw-Hill Book Company.

D. PROCESS FLOW AND INSTRUMENTATION

A process flow diagram (PFD) depicts flow directions of fluid and fluid movement in terms of mass per unit time (mass balance) and volume per unit time (Figure 3-3). The mass balance is the summation of all fluid quantities that enter and leave a piece of equipment. What leaves and enters must be equal. Since volume can be compressed or expanded, volume is not always in balance.

Process flow diagrams are important to determine the flow direction of liquid or vapor within the facility. Incompatible wastes should not flow in common piping or vapor recovery systems. In addition, process flow diagrams may indicate flow rates. High flow rates can cause equipment failures through erosion.

The simple process flow diagram (Figure 3-3) indicates that waste streams number 8 and 14 are vented directly to the atmosphere, and stream number 16 is discharged directly to the city sewer system. The permit writer should be satisfied that these discharges meet applicable NPDES and Clean Air Act requirements.

2. Piping and Instrumentation Diagram (P&ID)

A P&ID shows instruments such as valves, level and pressure controls, and temperature and pressure indicators used to control and monitor the operation of a tank. The permit writer should examine the diagram to assure that incompatible wastes will not be mixed because of facility design (see Figure 3-4).

Evaluation should include the following items:

- Whether appropriate liquid level control and venting control instrumentation are provided (they are of primary concern in a tank facility). All control mechanisms should be adequately sized.
- Whether a common vapor system or separate systems to handle incompatible waste are used.

3. Plot Plan

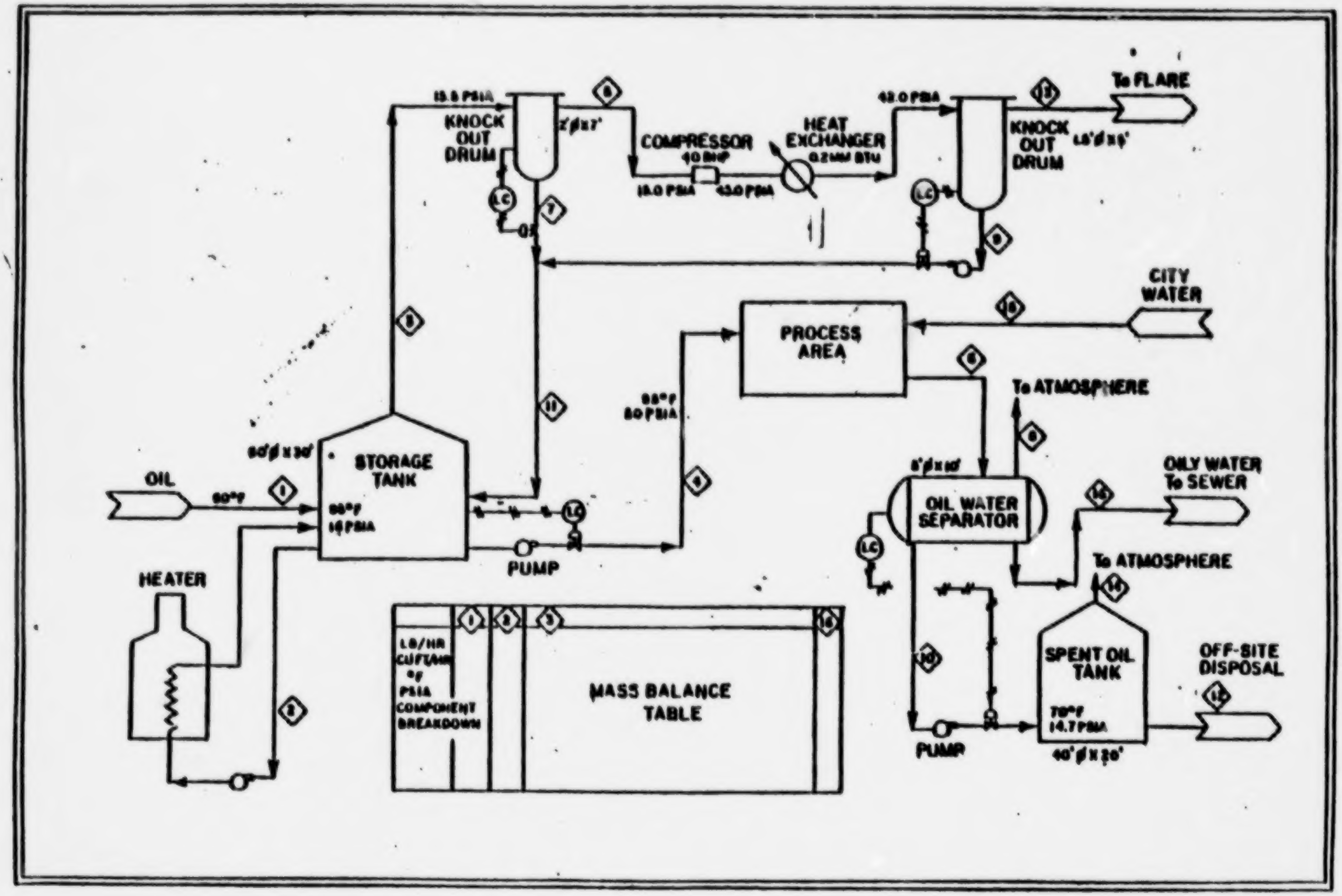
A plot plan of a facility with each piece of equipment drawn to scale locates each piece of equipment in relation to the entire facility. From a plot plan the adequacy of the following items can be evaluated:

- diking and drainage systems for tanks;
- space requirements between equipment;
- receiving areas for wastes.

4. Tank Diagrams and Data Sheets

A typical tank diagram (see Figure 3-5) and a typical tank data sheet (see Figure 3-6) are presented and should be used in conjunction with the P&ID.

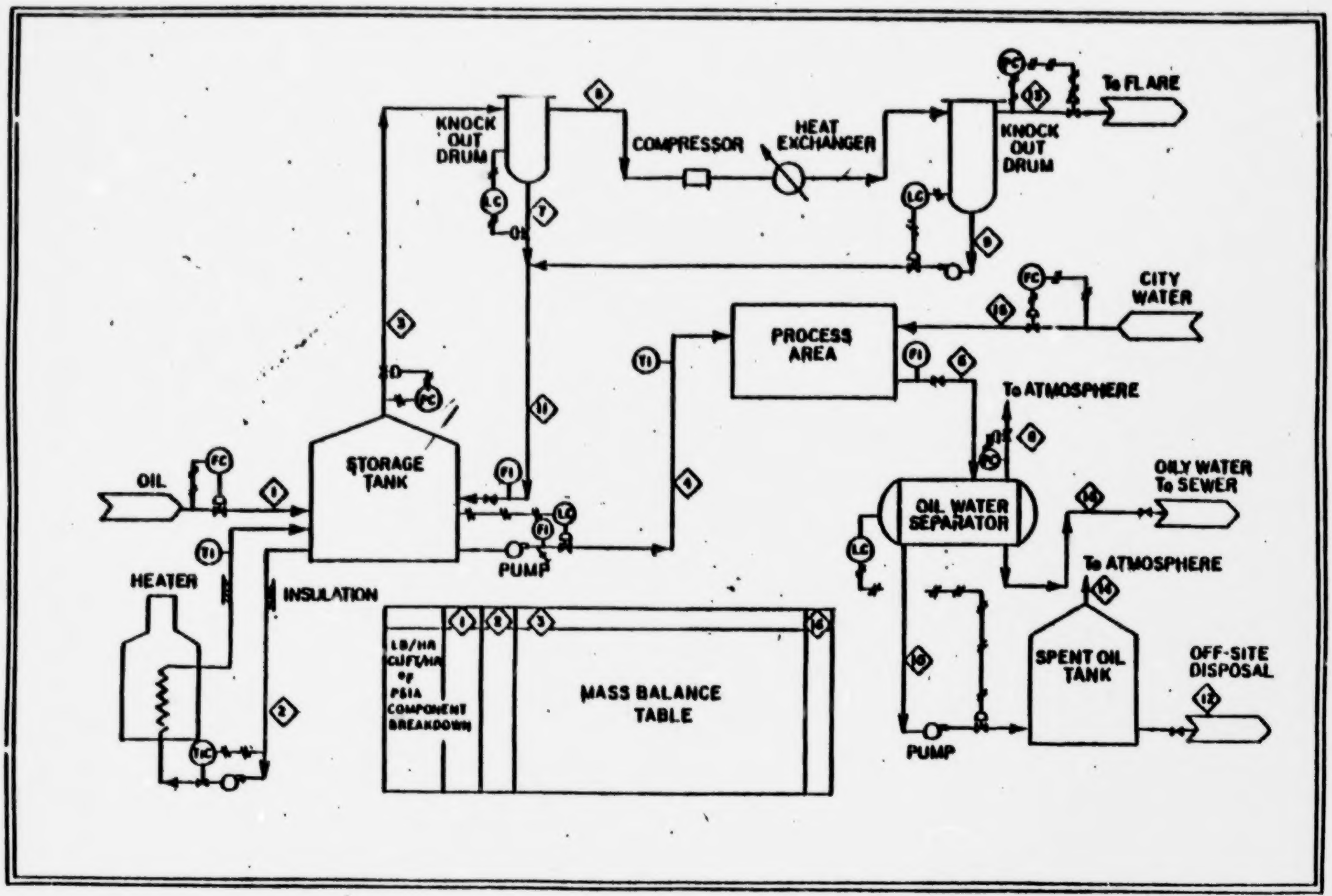
FIGURE 3-3


To FLARE
KNOCK OUT DRUM
15.5 PSIA
2'ø x 7'
COMPRESSOR
10 BHP
15.0 PSIA
43.0 PSIA
HEAT EXCHANGER
0.2 MM BTU
42.0 PSIA
KNOCK OUT DRUM
1.5'ø x 5'
CITY WATER
PROCESS AREA
To ATMOSPHERE
88°F
80 PSIA
60'ø x 30'
STORAGE TANK
80°F
14 PSIA
OIL
80°F
HEATER
PUMP
LC
OIL WATER SEPARATOR
5'ø x 10'
OILY WATER To SEWER
To ATMOSPHERE
SPENT OIL TANK
70°F
14.7 PSIA
40'ø x 20'
PUMP
OFF-SITE DISPOSAL
MASS BALANCE TABLE
LB/HR
CUFT/HR
°F
PSIA
COMPONENT BREAKDOWN
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

A SIMPLE PROCESS FLOW DIAGRAM

Source: Fred C. Hart Associates, Inc., 1980.

FIGURE 3-4


KNOCK OUT DRUM
COMPRESSOR
HEAT EXCHANGER
KNOCK OUT DRUM
To FLARE
CITY WATER
PROCESS AREA
To ATMOSPHERE
OILY WATER To SEWER
OIL WATER SEPARATOR
To ATMOSPHERE
STORAGE TANK
OIL
HEATER
INSULATION
PUMP
PUMP
SPENT OIL TANK
OFF-SITE DISPOSAL
LB/HR
CUFT/HR
°F
PSIA
COMPONENT BREAKDOWN
MASS BALANCE TABLE
FC
LC
PC
FI
TI
TIC

A SIMPLIFIED PIPING AND INSTRUMENTATION DIAGRAM

Source: Fred C. Hart Associates, Inc. , 1980.

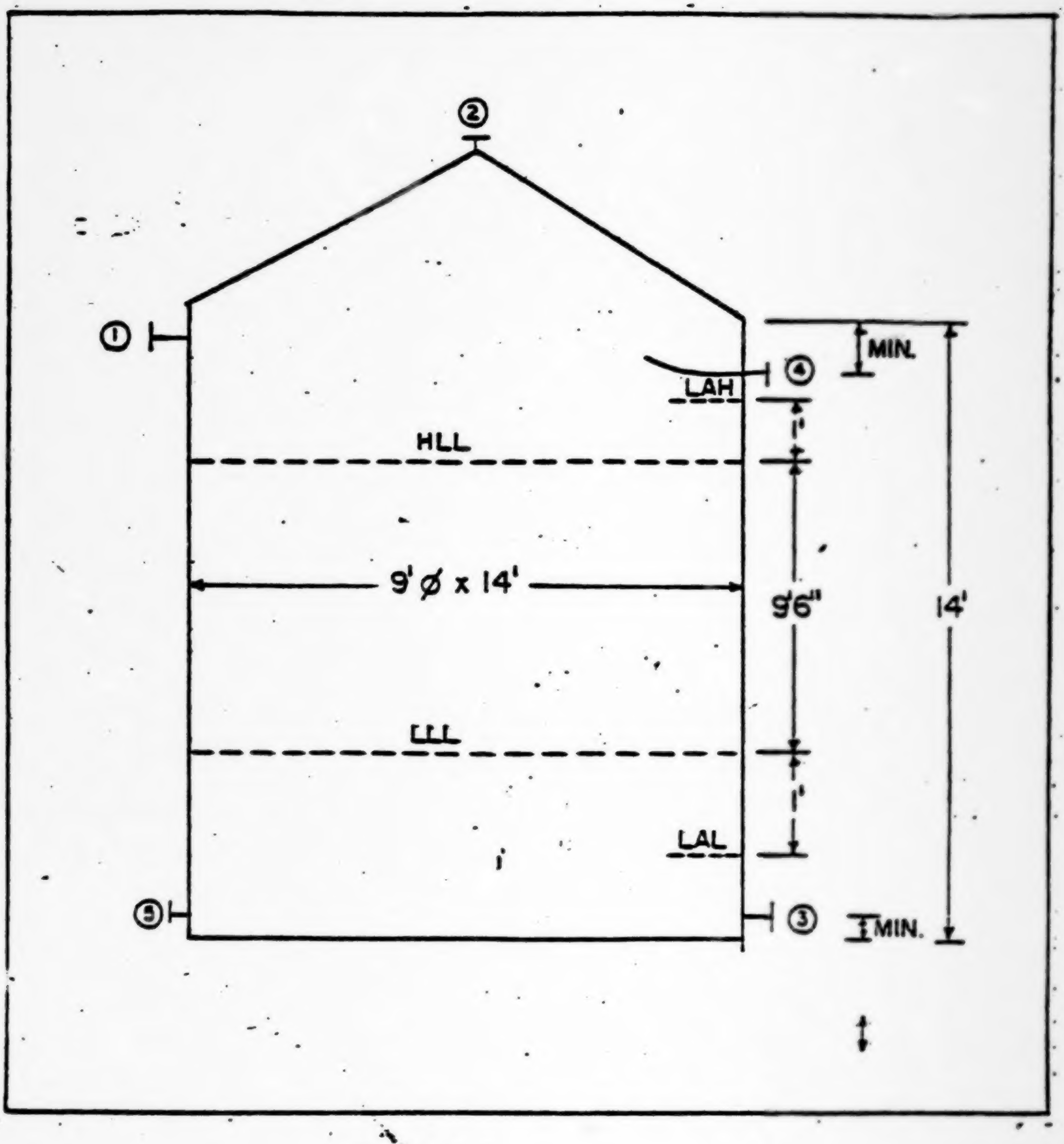

②
①
④
LAH
HLL
9'Ø x 14'
9'6"
14'
1'
LLL
1'
LAL
⑤
③
MIN.
MIN.

FIGURE 3-5

A SIMPLE TANK DIAGRAM

Source: Fred C. Hart Associates, Inc.

HLL = High liquid level; LAH = Level alarm high; LLL = Low liquid level; LAL = Level alarm low.

FIGURE 3-6

TYPICAL TANK DATA SHEET

PROCESS INFORMATION OPERATING DATA

LOC. OR NOZZ.	FLUID	FLOW LB./HR.	DENSITY LB./CU.FT.	TEMP. °F NORM.MAX/MIN	PRESS.PSIA NORM.MAX.	TIME	LL DATA FOR
1	LIQ&VAP	4539	0.754(MAX.)	95	16.2	RESIDENCE 3.0 MIN.	Level Control High(LCH) High Liquid Level(HLL) Level Alarm-High(LAH) Normal Liquid Level(NLL Level Alarm-Low(LAL) Low Liquid Level(LLL) Control Low(CL) Low Control Level(LCL)
2	VAPOR	3499	0.584	95	16.2		
3	LIQUID	1040	40.3(MIN.)	95	16.2		

VAPOR PRESSURE @ MAX. AMB. °F = PSIA
PROCESS CONTAMINENTS

MECHANICAL DESIGN REQUIREMENT

PRESS MARGIN: MIN SPEC. _______ + _______ = _______ PSI

MIN. DESIGN PRESS AT TOP _______ PSIG (MARG. + OPER.)

SYSTEM PSV SET AT _______ PSIG LOCATED

MIN. DESIGN TEMP °F @ PSIA

EXTERNAL PRESS DESIGN: FOR

VESSEL SUPPORT DATA: SKIRT_______LEGS_______LUGS_______SADDLES_______

HEIGHT_______MIN. ABV. GRADE FIREPROOFING_______

NOZZLES

	NOZZ. NO.	SERVICE	NO. REQ'D.	EST. SIZE	RATING & FACING	INT'L TYPE OR NOTE
INSTRUMENTS	J-6	Manway				
	J-5					
	J-4					
	J-3					
	J-2					
	J-1	PSV				
PROCESS	8					
	7					
	6					
	5	Drain	1	2"		
	4	Overflow	1	4"		
	3	Liquid	1	2"		
	2	Vapor Out	1	4"	20 FPS/1.4 psi/1000 ft.	
	1	Liq.&Vapor Feed	1	4"	20 FPS/1.7 psi/1000 ft.	

PSV = Press Sensing Valve

FPS = Feet Per Second

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CHAPTER 4

Inspection

Chapter Outline

A. Evaluation of an Inspection Plan

B. Tank External Inspection--Tank in Service

  1. Procedures

    a. Ladders, Stairways, Platforms, and Walkways
    b. Foundations
    c. Pipe Connections
    d. Overfilling Controls and Freeboard
    e. Protective Coatings
    f. Tanks Walls
    g. Tank Roofs

  2. Inspection Tools and Electromechanical Equipment

    a. Penetrant Dye Method
    b. Vacuum Box
    c. Ultrasonic Instruments

C. Tank Internal Inspection--Tank out of Service

  1. Preparation and Safety
  2. Roof and Structural Members
  3. Tank Shell
  4. Tank Bottoms

D. Inspection of Ancillary Equipment

  1. Visual Inspection of Pipes, Valves, and Fittings
  2. Visual Inspection of Heat Exchangers
  3. Inspection of Pumps and Compressors
  4. Visual Inspection of Instruments, Control Equipment, and Electrical Systems

E. Frequency of Inspection

F. Response to Leaks and Spills

CHAPTER 4

INSPECTION

Inspection and repair are the two major components of proper maintenance in any type of facility. Inspection is the foremost step in maintenance and is of prime concern to the permit writer because the inspection procedures and frequencies must be sufficient to prevent uncontrolled discharges to the environment.

This chapter covers procedures used to inspect tanks. Topics will include both external and internal visual inspection points where a tank and its auxiliary equipment should be inspected and how it should be inspected, a brief description of tools and electomechanical equipment utilized to perform inspection, and a rationale for determining frequencies of inspections.

The regulatory requirements for inspections of tanks include:

- a list of components and minimum inspection frequencies for external tanks inspections;
- a requirement for internal inspections with procedures and frequencies to be specified by the owner-operator; and
- a requirement that procedures for spill response and tank repair be specified in the contingency plan.[1]

A. EVALUATION OF AN INSPECTION PLAN

An inspection plan consists of a checklist of equipment and parts to be inspected, procedures for inspecting equipment, and frequency of inspection.

Table 4-1 is a sample checklist for inspecting a tank. A comprehensive plan should include procedures for inspecting each item in the list.

TABLE 4-1

TANK INSPECTION POINT LISTING

A. External Inspection -- Tank in Service

(1) Ladders, Stairways, Platforms, and Walkways
- corroding bolts
- cracked or spalled concrete pedestals
- low spots where water can collect

(2) Foundations
- erosion
- uneven settlement
- cracks and spalling in concrete pads, base rings, and piers
- deterioration of water seal between tank bottom and the foundation
- distortion of anchor bolts

(3) Pipe Connections
- external corrosion
- cracks and distortion

(4) Protective Coatings
- rust spots, blisters, and film lifting

(5) Tank Walls
- corrosion
- discoloration of paint surface
- cracks at nozzle connections, in welded seams, and in metal ligament between rivets
- cracks, buckles, and bulges

(6) Tank Roofs
- malfunctioning of seals
- blockage of water drains on roofs
- corrosion

(7) Overfilling Control
- malfunction of controls
- insufficient freeboard

B. Internal Inspection -- Tank out of Service

(1) Preparation
- check air quality inside tank
- roof and internal support for deterioration

(2) Roof and Structural Members
- malfunctioning of roof's seals
- corrosion
- loss of metal thickness

(3) Tank Shell
- corrosion of vapor space and liquid-level line
- cracking of plate joints
- cracking of nozzle connection joints
- bulges, holes, or cracks of lining (if the inside shell is coated)
- loss of metal thickness

(4) Tank Bottom
- corrosion pits
- sprung seams
- rivets for tightness and corrosion
- depressions in the bottom areas around or under roof supports and pipe supports
- bottom thickness
- unevenness of the bottom

C. Ancillary Equipment

(1) Pipes, Valves, and Fittings
- loss of metal thickness
- leaks
- corrosion or deterioration

(2) Heat Exchangers
- corrosion or pitting
- blisters
- erosion
- leaks

(3) Pumps and Compressors
- foundation cracks and uneven settling
- leaky pump seals
- missing anchor bolts
- excessive vibrations and noise
- depleted lubricating oil reservoir
- odor and smoke
- excessive dirt
- excessive corrosion
- excessive vibration of pumps
- leaks and cracks of assembly bolts, gaskets, cover plates, and flanges

(4) Instruments, Control Equipment, and Electrical Systems
- check proper operation of equipment by qualified personnel according to the manufacturer's recommended frequency and methodology

B. TANK EXTERNAL INSPECTION -- TANK IN SERVICE

1. Procedures[2]

A visual maintenance check is the simplest way to detect corroded or broken equipment.

An external inspection should include the following components of the tank: ladders, stairways, platforms, walkways, foundations, anchor bolts, pipe connections, overfilling controls, liquid level in tank, protective coatings, insulation tank walls, tank roofs, and valves.

a. Ladders, Stairways, Platforms, and Walkways. Even though the failure of any of these items would probably not cause leakage or rupture of a tank, they do pose significant safety hazards and are indicative of the overall condition of the tank facility. Stairway or walkway failure may be imminent if the concrete pedstals are cracked or spalled. Bolts should be checked for corrosion at the contact points. Rust stains showing through paint are evidence of corrosion. Low spots where water can collect should be examined carefully. The thickness of metals should be checked with calipers, and hammering can be used to check integrity. All defects found should be marked with paint and recorded; repair should proceed as soon as possible.

b. Foundations. Erosion and uneven settlement should be detected and corrected before serious damage occurs. The concrete pads, base rings, and piers should be examined for cracks and spalling. Such deterioration can be uncovered by scraping the suspected areas. The joint between the tank bottom and the concrete pad or base ring may have a seal for stopping water seepage, and, if so, it should be inspected for deterioration. Any wooden supports for tanks should be checked for rot by hammering. Metal loss in steel columns or piers can be checked by caliper readings against the original (or previously measured) thickness. Anchor bolts can be checked by visual inspection and hammering. Serious foundation settling is usually indicated by distortion of anchor bolts, buckling of columns, and excessive concrete cracking.

c. Pipe Connections. The pipe connections to a tank should be inspected for external corrosion by visual examination, scraping, and picking. Underground piping should be uncovered if severe soil contamination is suspected. The pipe should be scraped, cleaned, and visually inspected. In the event that a tank has settled excessively, special attention should be given to piping connections and piping as they may have cracked or become distorted.

d. Overfilling Controls and Freeboard. Overfilling control equipment should be inspected for corrosion, fouling, or other malfunctions. In open tanks the liquid level should be checked to ensure that adequate freeboard remains to prevent overtopping owing to wave or wind action or accumulated precipitation. Section IV contains additional details on inspection of measurement and process control devices.

e. Protective Coatings. Rust spots, blisters, and separation of the tank's protective coating from the tank can usually be detected by visual inspection or by scraping the film in suspected areas. Paint blisters usually occur on the roof and on the sunny side of the tank. Separation (or lifting) commonly occurs below leaks in the seam.

f. Tank Walls. External corrosion can occur on underground portions of tanks and related structures. If any foreign material has collected around the bottom of the shell, or if the tank is below grade, the shell should be inspected at least a foot below grade at several locations. Visual inspection, picking, scraping, and hammering are usually sufficient to locate corroded areas. When corrosion is found, thickness measurements should be taken at corroded points. This can be accomplished with ultrasonic or radiation-type instruments. The thickness measured externally should be compared with the thickness measured internally to locate the thinnest points and to determine the corrosion allowance left to operate the tank safely.

In addition to corrosion detection, the tank shell should be inspected for leaks, cracks, buckles, and bulges. Leaks can be spotted by a discoloration of paint in the area below the leak or by leak-testing devices such as ultrasonic or vacuum devices. Cracks can be found at nozzle connections, in welded seams, and the metal ligament points between rivets. Cracks, buckles, and bulges can initially be spotted by visual inspection, and their extent can be more thoroughly determined by techniques such as the magnetic-particle, penetrant-dye, or vacuum-box methods described below.

All the external valves on the tank should be visually inspected to ensure that the seating surfaces are in good condition. If there are signs of corrosion, the thickness should be measured. In cold weather, water draw-off valves should be inspected closely to detect possible damage from freezing. Pressure vacuum vents and breather valves should also be inspected for plugging, tight seals, and corrosion. All pressure gauges should be tested for accurate readings by using a deadweight tester or equivalent.

g. Tank Roofs. Regardless of appearance, tank roofs should be inspected thoroughly by hammering because of the strong possibility of corrosion. Some safety measures should be taken before and during the inspection, however, especially when the stability of the roof is questionable or harmful vapors may be present. Safety harnesses should be worn and planks long enough to span at least two structural supports should be laid as walkways until the structural safety of the roof is established. In addition, if the stored waste is volatile, tests for flammable vapors, generally performed with a portable combustible gas indicator, should be made prior to inspection.

Water drains on roofs should be inspected frequently for blockage, since the accumulation of precipitation can cause a floating roof to sink and fixed roofs to fail or corrode more rapidly.

2. Inspection Tools and Electromechanical Equipment[2]

When visual inspection suggests that tools are needed for a more detailed inspection, simple hand tools may be used as an initial aid. Tools such as a scraper, digger, or flange spreader are indispensable for visual inspection. Additional tools such as hammers, mirrors, magnifiers, magnets, and internal visual scopes are also helpful.

The mechanical measuring tools include calipers, micrometers, scales and tapes, wire gauges, and leveling and plumbing tools. The electronic devices include ultrasonic and electromagnetic instruments. In addition, there are chemical examination methods and destructive test methods.

The selection of a particular type of method is normally based on the inspection requirement and cannot be generalized. Therefore, this section will only attempt to familiarize the permit writer with some methods, as described below.

a. Penetrant-Dye Method. Penetrant dyes are often used to detect surface cracks on the outside of a tank that would not be revealed by a visual inspection. The penetrant is applied to a cleaned and dried surface by either brushing or spraying. After a few minutes of contact, a chemical developer is then sprayed onto the surface to give a white appearance upon dyeing. The dye stains the developer and exposes the extent and size of any defects.

b. Vacuum-Box Method. The vacuum box is an open box in which the lips of the open side are covered with a sponge rubber gasket, and the opposite side is glass. A vacuum gauge and air siphon connection are installed inside the box. The seam of the tank shell is first wetted with a soap solution, then the vacuum box is pressed tightly over the seam. The foam-rubber gasket forms a seal, and a vacuum is achieved inside the box by the air siphon. If any leak exists, bubbles will form inside the box and can be seen through the glass.

c. Ultrasonic Instruments. Ultrasonic instruments can be used to measure the tank's thickness and determine the location, size, and nature of defects. They can be used while the tank is in operation as only the outside of the tank needs to be contacted with the device. Two types of ultrasonic instruments, the resonance and the pulse type, are most commonly used for tanks. The pulse type utilizes electric pulses and transforms them into pulses of ultrasonic waves. The waves travel through the metal until they reach a reflecting surface. The waves then are reflected back, converted to electrical pulses, and show up on a time-base line of an oscilloscope. The instrument is calibrated by using a material of known thickness. Therefore, the time interval between the pulses corresponds to a certain thickness.

C. INTERNAL INSPECTION -- TANK OUT OF SERVICE[2]

1. Preparation and Safety.

The safety aspects preceding an internal inspection are very important. The tank should be emptied of liquid, freed of gases, and cleaned or decontaminated, if necessary. Respiratory protection should be provided for persons entering the tank. Several types of respiratory protection are available, ranging from highly protective self-contained breathing apparatus to less-protective air-purifying respirators. A complete discussion of safety procedures for internal tank inspections is beyond the scope of this manual. Persons not experienced in the conduct of internal tank inspections should contact the Occupational Safety and Health Administration for assistance in establishing safety procedures.

Adequate lighting must be provided inside the tank for a safe and effective inspection. The roof and internal supports should be inspected first, followed by a preliminary visual inspection of the shell to ensure that the tank is structurally stable.

2. Roof and Structural Members.

A visual inspection of the roof interior usually suffices. Thickness measurements should be performed, however, when corrosion is evident. Special attention should be given to interior roof seals.

3. Tank Shell.

The shell should be examined visually for corrosion. Tank shell thickness should be measured at representative points to ensure that the minimum thickness is maintained. While the bottom, the roof, and especially the shell are being inspected for corrosion, the plate joints and nozzle connection joints should be inspected for cracking. If any cracking is found, a more thorough investigation by magnetic-particle, penetrant-dye, or radiographic methods may be needed.

When the inside surfaces of a tank are lined with corrosion-resistant material, it is important to check for holes or cracks. Scraping or dye penetration is effective in locating pinholes and tight cracks. Bulges in the lining indicate leakage behind the lining and possible liner deterioration.

4. Tank Bottoms.

Tank bottoms should be hammered thoroughly to detect corrosion pits and sprung seams. The rivets should be checked at random for tightness and corrosion. The depressions in the bottom and the areas around or under roof supports and pipecoil supports should also be checked for corrosion. Unevenness of the bottom may be caused by settling and should be checked visually.

D. INSPECTION OF ANCILLARY EQUIPMENT[2]

1. Visual Inspection of Pipes, Valves, and Fittings

Inspections of pipes, valves, and fittings are usually conducted to note any losses in metal thickness owing to external or internal deterioration. These equipment parts are also subject to erosion or wear because of the effects of high liquid turbulence or velocity. It is preferable to inspect areas around pipe bends, elbows, tees, and other restrictions, such as orifice plates and throttling valves.

Visual inspection techniques include checking for leaks, misalignment, unsound piping supports, vibration or swaying, external corrosion, accumulations of corrosive liquids, and indications of pipe fouling. Thickness measurements while the pipes are in operation can be taken utilizing ultrasonic or radiographic techniques.

If the tank is out of service, piping can be opened at various places by removing a valve or fitting or by springing the pipe apart at flanged locations to permit internal visual inspection. A flashlight or extension light is needed in most cases and a probe-type instrument, such as a borescope, or a mirror and light will permit a more detailed view. If corrosion or erosion conditions are noted visually for some parts, radiographic or ultrasonic techniques can be used to inspect the entire length of pipe, if inaccessible to visual examination.

Pressure tests for pipes may include a design test for newly installed systems and leakage and tightness tests for existing systems. Various media used for pressure testing including water, steam, air, and carbon dioxide or other gases. [Note: Pressure tests with air are not recommended for tanks themselves because they are not likely to detect a leak below the liquid level of the tank and because they present a danger of rupturing the tank or causing expulsion of its contents.]

Piping systems that cannot be inspected visually are frequently pressure tested. They include:

- underground and other inaccessible piping;
- complicated manifold systems;
- small pipe and tubing systems;
- all systems after a chemical cleaning operation.

2. Visual Inspection of Heat Exchangers

Deterioration may be expected on all surfaces of exchangers and condensers that contact chemicals, water (both salt and fresh), and steam. The form of attack may be electrochemical, chemical, or mechanical, or a combination of the three. The attack may be further influenced by certain accelerating factors such as temperature, stress, fatigue, vibration, impingement, and high-flow velocity.

Appurtenant items to exchangers and condensers such as ladders, platforms, foundations, pipe connections, paint, and insulation can be inspected visually in a manner analogous to the inspection of the tank proper. The exchanger or condenser itself can be visually inspected for rust spots and blisters. If the unit is out of service, the inspection procedures can be more detailed. A scraper and a ball-peen hammer can be used in conjunction with a visual inspection to detect areas subject to excessive corrosion and erosion. Pressure tests utilizing a test fluid can also be used to detect leaks or excessive erosion or pitting.

3. Inspection of Pumps and Compressors

Mechanical wear is the predominant cause of deterioration of pumping and compression equipment although erosion and corrosion are also responsible for an appreciable amount of deterioration. Other deteriorating factors include improper operating conditions, piping stresses, cavitation, and foundation deterioration.

Routine visual inspection of pumps and compressors to determine general conditions during operation should include:

- foundation cracks and uneven settling;
- leaky pump seals;
- missing anchor bolts;
- leaky piping connections;
- excessive vibrations and noise;
- deteriorating insulation;
- depleted lubrication oil reservoir;
- missing safety equipment such as a pump coupling guard;
- burning odor or smoke;
- excessive dirt;
- excessive corrosion.

Since vibration can rapidly deteriorate a pump or compressor, periodic examination of the vibration level should be made using an electronic vibration meter. Inspection of all assembly bolts, gaskets, cover plates, and flanges should be conducted to detect leaks and cracks as a result of vibration or abnormal operating conditions.

4. Visual Inspection of Instruments, Control Equipment, and Electrical Systems

Instruments and control equipment are classified according to the type of measurement of function performed. They include:

- flow rate;
- level controls;
- temperature gauges;
- pressure gauges;
- control valves;
- alarms and emergency shut-off devices;
- analyzers.

The inspection of these instruments and controls includes checking transmission systems, power supplies, seals, panels, and other associated equipment. In many cases, instruments and controls are inspected daily by the operator since they are an integral part of the daily operation of the facility. All instrumentation and control equipment should be thoroughly inspected and calibrated according to the manufacturer's recommended frequency and methods.

Environmental conditions such as heat, moisture, chemical attack, and dirt are major reasons for deterioration of electrical systems. Insulations, enclosures, operating mechanisms, insulating and lubricating oils, protective relays, bearing, batteries, connectors and rectifiers are areas that should be inspected.

E. FREQUENCY OF INSPECTION

Inspection intervals for a tank and its equipment are either specified in the regulations or reviewed by the permit writer as part of the inspection schedule.

The frequency of most components of an external inspection of a tank have been specified in the regulations. Table 4-2 summarizes these requirements.

TABLE 4-2

REQUIRED INSPECTION FREQUENCIES

Inspected Daily

- overfilling control systems
- data from monitoring equipment (e.g., pressure and temperature gauges)
- level of waste in uncovered tanks

Inspected Weekly

- above-ground portions of tank (e.g., exterior of tank shell and roof)
- area immediately surrounding tank

As stated in §264.15(b), the frequency of inspection for other items should be based on the rate of possible deterioration of the equipment and the probability of an environmental or human health incident if the deterioration or malfunction goes undetected. The §264.194(b) requirements for periodic comprehensive tank inspections specify the following additional factors to be used in determining inspection intervals:

- material of construction of tank;
- type of erosion or corrosion protection used;
- characteristics of waste being stored;
- rate of corrosion or erosion observed during previous inspections.[1]

The expected service life of the tank can be a useful tool for establishing a minimum inspection frequency. For example, a tank with an expected service life of 25 years might initially be subjected to a comprehensive inspection every 3 years to establish the actual rate of corrosion or deterioration. As the tank approaches the end of its service life and the probability of leaks or ruptures increases, however, the inspection frequency should be increased to every 1 or 2 years.

In some cases the owner or operator may prefer to conduct more frequent comprehensive external inspections of the tank to avoid the expense of frequent internal inspections. In the example cited above, the owner-operator could initially conduct annual external inspections, which include intensive measurements of tank shell thickness (i.e., one measurement per square yard of surface area) and reduce the frequency of internal inspections to once every 5 years. As the condition of the tank deteriorates, however, the frequency of internal inspections should increase to every 1 or 2 years.

F. RESPONSE TO SPILLS AND LEAKS

Section 264.194(c) of the standards for inspection of hazardous waste tanks provides that owners or operators must specify the procedures they intend to use to respond to tank spills or leakage, including procedures and timing for expeditious removal of leaked or spilled waste and repair of the tank.

The procedures specified by the owner-operator will depend largely on site-specific circumstances. Factors will include the permeability if the area surrounding the tank, availability of excess capacity for emptying the tank, and the materials of construction of the tank.

Table 4-3 summarizes the types of incidents likely to occur at a tank facility that should be addressed in the contingency plan.

TABLE 4-3

OPERATIONAL PROBLEMS OF TANKS[4]

Bulk Storage Facilities -- Tank Farms and Tankage

- Overfilling of tanks
- Rupture of tanks
- Leaks in tanks, pipes, valves, and fittings
- Leaks in containment dikes
- Inadequate dike volume to hold contents of leaking tanks
- Water flow from diked area through open dike valve
- Leaks from pump seals and maintenance
- Level instrument failure allowing tank overfilling
- Piping damage by collision with mobile equipment
- Spills from tank bottom cleanout and sludge disposal
- Spills from pipe and tankage changes

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CHAPTER 5

COMMON TREATMENT PROCESSES OCCURRING IN TANKS

A. Chemical Oxidation

1. Oxidation Processes
2. Types of Wastes Treated by Chemical Oxidation
3. Process Design and Operating Parameters

    a. Type of Tank
    b. Selecting Materials for the Oxidation Process

B. Chemical Reduction

1. Reduction Processes
2. Types of Waste Treated by Chemical Reduction
3. Process Design and Operating Parameters

C. Neutralization

1. Process Description
2. Application of Neutralization Process
3. Types of Tanks
4. Environmental Impacts

D. Precipation, Flocculation, and Sedimentation

1. Precipitation

    a. Process Description
    b. Process Design and Operating Parameters

2. Flocculation

    a. Process Description

3. Sedimentation

    a. Process Description
    b. Process Design and Operating Parameters

4. Precipitation, Flocculation, and Sedimentation Applications to Hazardous Wastes

    a. Iron and Steel Industry
    b. Aluminum Industry
    c. Copper Industry
    d. Metal Finishing Industry
    e. Inorganic Chemicals Industry
    f. Sludge Thickening

5. Environmental Considerations

CHAPTER 5

COMMON TREATMENT PROCESSES OCCURRING IN TANKS

The service life of a tank can be prematurely shortened because of interactions among the wastes with other wastes, with the tank's construction materials, and with the treatment process or treatment reagents. To avoid adverse effects the regulation (40 CFR 264.13) requires that a waste analysis be performed before treating, storing, or disposing of hazardous waste. In addition to this general requirement, the operating requirements for tanks (40 CFR §264.192(a)) state that "wastes and other materials (e.g., treatment reagents) which are incompatible with the material of construction of the tank must not be placed in the tank unless the tank is protected from accelerated corrosion, erosion, or abrasion through the use of: (1) An inner liner or coating which is compatible with the waste or material...; or (2) Alternative means of protection."

The following are common operating problems associated with in-tank processes discussed in this chapter.

1. Corrosion. Corrosion of a tank may be accelerated by the treatment process itself or by the chemical reagents used to treat the waste. For example, chromic acid (an oxidizing agent) generally corrodes all metals. It would therefore, be inappropriate to treat chromic acid by neutralization or precipitation in a steel tank unless the tank is lined with a material that is relatively inert to chromic acid (e.g., glass, polyethylene, or PVC).

2. Salting and scaling. Salting and scaling is the formation of an insulating layer at heat transfer surfaces that could contribute to the failure of tanks and the subsequent escape of hazardous waste to the environment. Salting and scaling may be reduced or prevented by preliminary treatment of the influent waste stream or by other operational controls.

3. Pressure and heat. High pressure or heat caused by mixing wastes that collectively generate large amounts of gaseous emissions or result in an exothermic reaction may cause tanks to explode, warp, or weaken unless the tank has been designed to withstand high pressure or temperature. Toxic or flammable gases may also be emitted as a result of process reactions.

4. Liquid flow rate and mechanical abrasion. Mechanical abrasion from materials contained in the waste, high liquid flow rates, or high velocity mixing, may damage the construction materials of tanks, pumps, or ancillary equipment. Points of contact experiencing the most wear are, for example, nozzle necks, pump cases, valve seats, and pipe fittings. In order to prevent erosion, it is important to match the construction material of the tank and ancillary equipment with the abrasion characteristics of

the wastes expected to be treated, the anticipated liquid flow rate of the treatment process, and the energy generated or dissipated by mixing devices.

In order to determine whether a treatment process and its associated reagents are suitable for the treatment of a particular waste within a particular type of tanks, one must consider several factors. A treatment trial test can be conducted to examine the possibility of heat evolution or gas evolution, the compatibility of the treatment process intermediates and end products, and the compatibility of any added reagents with the tank's construction materials and design features.

This chapter is meant to provide an overview of the treatment processes that commonly occur in tanks and the possible interactions of the treatment processes with a tank. The five treatment processes described herein and the potential areas of process-tank interaction are as follows:

(1) chemical oxidation - corrosion, abrasion owing to mixing, high heat;

(2) chemical reduction - corrosion, abrasion owing to mixing, high heat;

(3) neutralization - corrosion, high heat or pressure, abrasion owing to mixing;

(4) precipitation - corrosion, abrasion due to mixing, scaling;

(5) sedimentation - corrosion, salting scaling.

A. CHEMICAL OXIDATION

1. Oxidation Processes[2]

The processes discussed here are based on chemical oxidation as differentiated from thermal, electrolytic, and biological oxidation. Chemical oxidation is a process in which the oxidation state of a substance is increased (i.e., the substance loses electrons). Chemical oxidation in water and wastewater treatment is a method for detoxifying objectionable and/or toxic substances. These substances include:

- inorganic substances (e.g., Mn^{2+}, Fe^{2+}, S^{2-}, CN^{-}, $SO_3{}^{2-}$);
- organic substances (e.g., phenols, amines, humic acids, odor- or color-producing or toxic compounds, bacteria, and algae)

Chemical oxidation processes most often used include:

- oxygenation or aeration;
- ozonation
- oxidation with hydrogen perioxide (very limited use);
- oxidation with potassium permanganate;
- chlorination or hypochlorination;
- oxidation with chlorine dioxide;
- oxidation with chromates or dichromates.

Table 5-1 is a listing of oxidants used to treat various wastes.

2. Types of Waste Treated by Chemical Oxidation[3]

Liquids are the primary waste form treatable by chemical oxidation. The most powerful oxidants are relatively nonselective; any easily oxidizable material in the waste stream will, therefore, be treated. For example, if an easily oxidizable organic solvent was used, little of the chemical effect of the oxidizing agent would be available for further oxidation.

Gases have been treated by scrubbing with oxidizing solutions for the destruction of odorous substances, such as certain amines and sulfur compounds. Potassium permanganate, for instance, has been used in certain chemical processes, in the manufacture of kraft paper, and in the rendering industry. Oxidizing solutions are also used for small-scale disposal of certain reactive gases in laboratories.

Oxidation has limited application to slurries, tars, and sludges. Because other components of the sludge, as well as the material to be oxidized, may be attacked indiscriminately by oxidizing agents, careful control of pH, etc., are required to ensure that the desired components are being oxidized.

Chemical oxidation can be used to treat both organic and inorganic waste components. Since some oxidizing agents may react violently in the presence of significant quantities of readily oxidizable organic material, either the organic matter or the oxidizing agent should be added slowly. Sudden large additions should be avoided.

The primary use of chemical oxidation for hazardous waste treatment is in the conversion and destruction of cyanides from plating operations where metals, such as zinc, copper, and chromium, are present.

TABLE 5-1

OXIDATION WASTE TREATMENT APPLICATION[3]

Oxidant	Waste
Ozone	Phenols Chlorinated hydrocarbons
Air (atmospheric oxygen)	Sulfites Sulfides Ferrous iron
Chlorine gas	Sulfide Mercaptans
Chlorine gas and caustic	Cyanide
Chlorine dioxide	Cyanide Diquat Paraquat
Sodium hypochlorite	Cyanide Lead
Calcium hypochlorite	Cyanide
Potassium permanganate	Cyanide - organic odors Lead Phenol Diquat Organic sulfur compounds Rotenone Formaldehyde
Permanganate	Manganese
Hydrogen peroxide	Phenol Cyanide Sulfur compounds Lead
Nitric acid	Benzidene

3. Process Design and Operating Parameters

As a physicochemical process, the design of a system for the chemical oxidation of a waste material involves considering the following design and operating parameters:

- type of tank (or reactor);
- mixing;
- location of inlet and outlet pipes;
- pH or other process control;
- temperature control;
- materials selection.

Both tank selection and materials selection are discussed below.

a. Type of Tank. Types of vessels, containers, or tanks (commonly called reactors) in which chemical and biological reactions are carried out include batch, plug flow, continuous, packed or fluidized bed.

b. Selecting Materials for the Oxidation Process. When selecting the materials of construction for the oxidation process, one must protect the tank against the corrosive effects of the oxidizing agent. Specifying a material of construction usually involves three stages: listing the requirements, selecting and evaluating the candidate materials, and choosing the most cost-effective material. A valuable source of information on selection of materials of construction is "How to Select Materials" in the November 3, 1980, issue of Chemical Engineering (reprints from which are available).

The most important factor in selecting material is performance regarding corrosion. The information listed in Table 5-2 is valuable in estimating materials' corrosion performance. Additional information on corrosion is provided in the technical resource document titled "Compatibility of Wastes in Hazardous Waste Management Facilities."

B. CHEMICAL REDUCTION

1. Reduction Processed[8]

Reduction-oxidation, or Redox, reactions are those in which the oxidation state of at least one reactant is raised while that of another is lowered. Reduction is used to treat wastes in such a way that the reducing agent lowers the oxidation state of a substance, reduces its solubility, or transforms it into a form that can be more easily handled.

Base metals such as iron, aluminum, zinc and sodium compounds are good reducing agents. Sulfur compounds are among the more common reducing agents.

TABLE 5-2

INFORMATION FOR ESTIMATING CORROSION AGAINST PERFORMANCE[5]

Process Conditions

Main constituents (identity and amount) of waste
Impurities (identify and amount) in waste
Temperature
pH
Degree of aeration
Velocity of agitation
Pressure
Estimated range of each variable
Environmental conditions

Type of Application

What is function of part or equipment?
What effect will uniform corrosion have on serviceability?
What effect will localized corrosion have on usefulness?
Will there be stresses present? Is stress-corrosion cracking a possibility? Are crevice or pitting corrosion likely to occur?
Is design compatible with the corrosion characteristics of the material?
What is the desired service life?

Experience

Has material been used in identical situations? With what specific results?
If equipment is still in operation, has it been inspected?
Has material been used in similar situation? What was performance, and specifically what are differences in old and new situation?
Any pilot-plant experience?
Any plant corrosion-test data?
Have laboratory corrosion tests been run?
What literature is available?

2. Types of Waste Treated by Chemical Reduction[8]

Liquids are the primary waste form treatable by chemical reduction. the most powerful reducing agents are relatively nonselective; any material in the waste stream that is relatively easily reduced can, therefore, be affected.

Reduction has limited application to slurries, tars, and sludges, because of the difficulties of achieving intimate contact between the reducing agent and the hazardous constituent. Consequently, the reduction process would be very inefficient. In general, hazardous materials occurring as powders or other solids would usually have to be dissolved prior to chemical reduction.

Table 5-3 lists some of the more common wastes and reducing agents that undergo the reduction process.

3. Process Design and Operating Parameters

Analogous to the oxidation process, the design of a system for the chemical reduction of a waste material involves the following design and operating parameters:

- type of tank (or reactor);
- reaction rates;
- mixing;
- location of inlet and outlet pipes;
- pH control;
- temperature control;
- materials selection.

Both type of tank and materials selection have been discussed in the oxidation section of this chapter.

In general, very simple equipment is required for chemical reduction. This includes storage vessels for the reducing agents and perhaps for the wastes, metering equipment for both streams, and contact vessels with agitators to provide suitable contact of reducing agent and waste. Some instrumentation is required to determine the concentration and pH of the waste and the degree of completion of the reduction reaction. The reduction process may be monitored by an oxidation-reduction potential (ORP) electrode. This electrode is generally a piece of noble metal (often platinum) that is exposed to the reaction medium and produces an EMF (electromotive force) output that is empirically relatable to the reaction condition by revealing the ratio of the oxidized and reduced constituents.

TABLE 5-3

REDUCTION WASTE TREATMENT APPLICATIONS [8]

Waste	Reducing Agent
Chromium (VI)	Sulfur dioxide (often flue gas)
	Sulfite salts
	sodium bisulfite
	sodium hydrosulfite
	Ferrous sulfate
	Waste pickle liquor
	Powdered waste aluminum
	Powdered metallic zinc
Mercury	Sodium borohydride
Tetra-alkyl-lead	Sodium borohydride
Silver	Sodium borohydride

C. NEUTRALIZATION[9]

1. Process Description

The process of neutralization is the interaction of an acid with a base. The term "neutralization" is often used to describe adjustment of pH to values within the neutral range of 6.0 to 9.0.

The actual process of neutralization is accomplished by the addition of an alkaline material to an acidic material or by adding an acidic to an alkaline material, as determined by the required final pH. The primary products of a neutralization reaction are a salt and water.

2. Application of Neutralization Process

Neutralization is a treatment process of demonstrated technical and economic feasibility that is in full-scale use in a wide spectrum of industries. A sample list of industries employing this process is presented in Table 5-4. Neutralization finds its widest application in the treatment of aqueous wastes containing strong acids such as sulfuric and hydrochloric, or strong bases such as caustic soda and sodium hydroxide. The process can, however, be used with nonaqueous materials (for example, acidic phenols, which are insoluble in water). Although neutralization is a liquid phase phenomenon, it can also treat both gaseous and solid waste streams. Gases can be handled by absorption in a suitable liquid phase, as in the case of alkali scrubbing of acid vapors. Slurries can be neutralized, with due consideration for the nature of the suspended solid and its dissolution properties. Sludges are also amenable to pH adjustment, but the viscosity of the material complicates both the process of physical mixing and the resultant contact between acid and alkali, which is essential to the treatment. In principle, even tars can be neutralized, although the problems of reagent mixing and contact are usually severe, making the process impractical in most instances. Solids and powders that are acidic or basic salts can also be neutralized if they are dissolved prior to initiating the neutralization process.

Some of the more common applications for pH treatment of acidic and alkaline wastes are described in the following paragraphs.

Acid Exhausts - Industrial processes that utilize acids, e.g., sulfuric, nitric, or hydrochloric, frequently have problems with acid mist in the exhaust. Scrubbing with water on packed bed columns produces an acid-free gas, but the spent water must be neutralized. Alkali is usually added automatically to produce a water stream with a pH of 6.5-7.5 that can be discharged or recycled. In similar systems, flue gas desulfurization units absorb and neutralize sulfur oxides with alkalies such as lime, limestone, dolomite, or caustic soda.

TABLE 5-4

MAJOR INDUSTRIES USING NEUTRALIZATION[9]

INDUSTRY	WASTEWATER pH RANGE
Pulp and paper	Acidic & basic
Dairy products	Acidic & basic
Textiles	Basic
Pharmaceuticals	Acidic & basic
Leather tanning and finishing	Acidic & basic
Petroleum refining	Acidic & basis
Grain milling	Acidic & basis
Fruits and vegetables	Acidic & basic
Beverages	Acidic & basic
Plastic and synthetic materials	Acidic & basic
Steel pickling	Acidic
By-product coke	Basic
Metal finishing	Acidic
Organic chemicals	Acidic & basic
Inorganic chemicals	Acidic & basic
Fertilizer	Acidic & basic
Industrial gas products	Acidic & basic
Cement, lime, and concrete products	Basic
Electric and steam generation	Acidic & basic
Nonferrous metals-aluminum	Acidic

Petrochemical Waste Streams - Neutralizaiton is applied to: (1) washwaters, acid or alkaline, (2) spent caustics, (3) acid sludges (4) spent acid catalysts. Sulfuric acid and carbon dioxide from flue gases are both used to treat spent caustic wastes. Pits filled with lime, limestone, and even oyster shells (a source of calcium carbonate) are utilized to neutralize spent acid sludges.

Sulfuric Acid Pickle Liquor - In small-scale operations (less than 5,000 gpd) neutralization of pickle liquor from steel cleaning operations can be performed in a batch process, usually with quicklime. typically, pickle liquor contains on the order of 70 grams of iron and 170 grams of sulfate per liter (approximately 5 percent sulfuric acid by weight). Large waste streams can be handled in continuous flow systems, and other suitable alkaline agents may be employed. If calcium-based materials are utilized in the neutralization, calcium sulfate will form a product sludge, which is usually dewatered by vacuum filtration or placed in a lagoon. The formation of a flocculated ferrous hydroxide precipitate (at neutral pH) can produce a solid with poor settling and filtering properties. Thus an oxidation step is often employed since ferric hydroxide is very insoluble, and there is an optimum ratio of ferric to ferrous ions at which the sludge can be handled most readily.

3. Types of Tanks

The required equipment for neutralization is simple: storage and reaction tanks with accessory agitators and delivery systems. The tanks may be of any shape, but must be properly baffled to allow adequate mixing and prevent "short-circuiting." Frequently, the neutralization is carried out in a series of tanks to provide better control of the final pH.

Appropriate instrumentation must be provided and include pH measurement (and possible recording) devices with appropriate sample pumps. The feed of neutralizing agent may be regulated automatically by the pH monitoring unit, depending on the requirements of the individual system.

The design of storage facilities for neutralizing agents depends on the chemical reagents employed in the treatment process. Caustic solutions and acids may be stored in the open, but quicklime should be kept in waterproof silos, hoppers, or even bags. Delivery systems depend on the physical form of the reagents. Liquids may be transferred with pumps, while slurries can be moved through gravity piping, pumps, or open flumes. Ancillary equipment might include installations such as equalization basins, clarifiers, or vapor removal systems, depending on the specific neutralization scheme.

In dealing with acids and alkalies, appropriate materials of construction are required to provide reasonable service life for equipment. Corrosion may result in deterioration of a construction material, e.g., lead is attached by hydrochloric acid. In many cases, the specific concentration of a reagent is important in selecting the correct material used in pumps, pipes, tanks, etc. Examples of materials recommended for handling different acids and alkalies at ambient temperature are:

sulfuric acid (75-95 percent concentration) - lead
(10 percent concentration) - lead or rubber

hydrochloric acid (concentrated or dilute) - rubber

sodium hydroxide (concentrated - 316 stainless steel (SS) or rubber

(dilute) - 316 stainless steel (SS), rubber, carbon steel, or cast iron

calcium hydroxide - 316 SS, rubber, or carbon steel

Other less commonly used materials include glass, metal alloys such as monel, plastics, such as PVC, and even wood. The expense of such materials frequently precludes their use except for small-scale applications or in situations where there is no alternative. It is important to realize that a vessel need not be constructed entirely of one material; it may be lined with lead, rubber, glass, plastic, or other corrosion-resistant materials. Expected length of service, temperature of operation, desired physical strength, liquid flow rate, and mechanical abrasion are some of the other factors to be considered in selecting materials.

In general, fiberglass tanks or tanks lined with an organic material are used for storing acids that present corrosion problems in contact with most metals.

4. Environmental Impacts

After neutralization a waste stream will usually show an increased total dissolved solids content because of the addition of the chemical agent, but there may also be an accompanying reduction in the concentration of heavy metals if the treatment proceeds to the basic pH range. Conversely, in neutralization involving the addition of acid to alkali, there is the possibility of dissolution of metal-containing solids. This may, on occasion, be disadvantageous, particularly if the suspended matter is slated for removal, e.g., by filtration. For example, the anions resulting from neutralization of sulfuric and hydrochloric acids are sulfate and chloride, respectively. These ions are not considered hazardous, but there are recommended limits for discharge, based primarily on problems in drinking water. The common cations present after neutralization involving caustic soda and lime (or limestone) are sodium and calcium (possibly magnesium), respectively. These ions are not toxic and there are no recommended limits; calcium and magnesium are, however, responsible for water hardness and the accompanying scaling problem. Limestone neutralization converts the carbonate to harmless carbon dioxide gas.

With regard to atmospheric emissions, one must be cautious not to neutralize wastewater streams indiscriminately. Acidification of streams containing certain salts, such as sulfide, will produce toxic gases. If there is no satisfactory alternative, the gas must be removed through scrubbing or some other treatment. In cases where solid products are formed (as in the precipitation of calcium sulfate, or heavy metal hydroxides), clarifier/thickeners and filters must be provided. If the precipitate is of sufficient purity, it would be a salable product; otherwise, a disposal scheme must be devised.

D. PRECIPITATION, FLOCCULATION, AND SEDIMENTATION[11]

Precipitation, flocculation, and sedimentation are discussed together in a single section because in waste treatment they are most commonly used together, as consecutive treatments to the same stream. Precipitation removes a substance in solution and transforms it into a second phase, often in the form of solid particles that may be small or even colloidal. Flocculation transforms small suspended particles into larger suspended particles so that they can be more easily removed. Sedimentation removes the suspended particles from the liquid.

1. Precipitation

a. Process Description. Precipitation is a physicochemical process whereby some or all of a substance in solution is transformed into the solid phase and thereby removed from solution. Precipitation involves an alteration of the chemical equilibrium relationships affecting the solubility of the component(s). This alteration can be achieved by a variety of means. Most precipitation reactions for indistrial or waste treatment purposes are induced by one or a combination of the following steps:

- adding a substance that will react directly with the substance in solution to form a sparingly soluble compound,
- adding a substance that will cause a shift in the solubility equilibrium to a point that no longer favors the continued solubility of the substance originally in solution
- changing the temperature of a saturated or nearly saturated solution in the direction of decreased solubility; since solubility is a function of temperature, this change can cause ionic species to come out of solution and form a solid phase.

The most common precipitation reactions involve the removal of inorganic ionic species from an aqueous medium. For example, zinc chloride is highly soluble in water, as is sodium sulfide. Zinc sulfide, however, has an extremely low solubility in water. Thus, if an aqueous solution of zinc chloride is mixed with an aqueous solution of sodium sulfide, zinc ions and sulfide ions will rapidly combine to form solid zinc sulfide particles.

It is important to recognize that the term precipitation, as strictly defined, refers only to the conversion of dissolved substances into insoluble ones in order to facilitate their subsequent removal from the liquid phase. Precipitation per se does not refer to any of the liquid-solid separation processes that are required to remove the precipitated solid particles from the original volume of liquid. In order to effect the removal of precipitated particles from a volume of liquid, it is very often necessary to apply additional process steps, and these often involve flocculation, sedimentaton, and/or some control that will determine the final particle size -- and produce an easily separable solid (or crystal).

b. Process Design and Operating Parameters. The parameters of interest for precipitation include the time required for reaction, the solubility product of the substance to be precipitated, and the effect of the reaction upon the tank construction materials and types of tanks.

Physically, most precipitation reactions are carried out by adding the appropriate chemicals to the solution and mixing thoroughly. Reagents should be added in a manner that minimizes contact of the concentrated reagent with the tank surface. Although most precipitation reactions take place extremely rapidly, a moderate amount of time is usually required to allow the chemicals to be dispersed throughout the solution. Characteristically, the solid particles, when first formed, are very small. Depending on the nature of the chemical system involved and the types of further treatment applied, the solid particles can remain as submicroscopic precipitation nuclei, or very small colloidal particles; or they can grow into larger particles. Since mixing can shorten the dispersion time of chemicals, some type of mixing equipment should be used.

The solids formed by precipitation are salts and should not pose severe corrosion problems. The chemicals added to the waste in order to induce precipitation are, however, often corrosive in nature, such as concentrated hydroxides or strong acids. Again, caution should be taken when adding these chemicals to the waste and upon mixing of the chemicals in order to minimize contact of concentrated agents with the tank surface.

2. Flocculation

a. Process Description. The term flocculation as defined here encompasses all of the mechanisms by which the suspended particles agglomerate into larger particles, including the addition of flocculating agents.

Many liquid-solid separation processes, such as sedimentation, are based on the use of gravitational and/or inertial forces to remove solid particles from a liquid. It is generally true that the larger the particle size, the easier will be the removal of the particle from the liquid.

A variety of mechanisms is involved in flocculation whereby small particles are made to form larger particles.

Most of these mechanisms involve surface chemistry and particle charge phenomena. In simple terms, these various phenomena can be grouped into the following two sequential mechanisms:

- chemically induced destabilization of the repulsive surface-related forces, thus allowing particles to stick together when contact between particles is made;
- chemical bridging and physical enmeshment between the now nonrepelling particles, thus allowing for the formation of large particles.

Once suspended particles have been flocculated into larger particles, they can usually be removed from the liquid by sedimentation, provided a sufficient density difference exists between the suspended matter and the liquid.

As in precipitation, the solids formed by flocculation are salts and should not pose severe corrosion problems. Chemical reagents that are corrosive in nature should, however, be added to a tank and mixed with caution, so as to minimize contact of the reagent with the tank surface.

3. Sedimentation

a. Process Description. Sedimentation is a physical process whereby particles suspended in a liquid are made to settle by means of gravitational and inertial forces acting on both the particles suspended in the liquid and the liquid itself. Basically, particles settle out of a liquid by creating conditions in which the gravitational and inertial forces acting on the particle in the desired direction of settling are greater in magnitude than the various forces (drag forces, inertial forces) acting in the opposite direction. This force differential causes the particles to travel in the desired direction.

The fundamental elements of most sedimentation processes are:

- a tank or container of sufficient size to maintain the liquid in a relatively quiescent state for a specified period of time;

- a means of directing the liquid to be treated into the tank in a manner that is conducive to settling;
- a means of physically removing the settled particles from the liquid (or the liquid from the settled particles, whichever the case may be).

Sedimentation can be carried out as either a batch or a continuous process. Continuous processes are by far the most common, particularly when large volumes of liquid are to be treated.

Depending on the specific process configuration, the settled particles are either removed from the bulk of the liquid, or the liquid is separated from the settled particles by decantation. The end result, and single purpose, of sedimentation is the separation of liquids from solids. The fraction of liquid containing the settled particles is commonly referred to as "sludge."

b. Process Design and Operating Parameters. Because sedimentation is purely a physical separation, the type of tank used to provide the separation is the most important factor. Since there is little control over the particle size or density, the only method that can be used to accommodate these factors is to design tanks to handle the different settling characteristics of various wastes.

Sedimentation can be carried out in rudimentary settling ponds (surface impoundments), conventional settling basins, or in more advanced clarifiers that are often equipped with built-in flocculation zones and tube-like devices that enhance settling.

In settling ponds, the liquid is merely decanted as the particles accumulate on the bottom of the pond and eventually fill it. Often the pond is periodically scraped by mechanical shovels, draglines, or siphons. Sedimentation basins and clarifiers are more sophisticated and usually employ a built-in solids collection and removal device such as a sludge scraper and draw-off mechanism. Sedimentation basins tend to be rectangular in configuration, usually employ a belt-like collection mechanism, and tend to be used more for the removal of easily settleable particles from a liquid.

Clarifiers are generally circular and are usually used in applications that involve precipitation and flocculation in addition to sedimentation. Very often all three processes take place within the same piece of equipment, since many clarifiers are equipped with separate zones for chemical mixing and precipitation, flocculation, and settling. Certain clarifiers are equipped with low lift turbines that mix a portion of the previously settled precipitates with the incoming feed. The practice has been show to enhance certain precipitation reactions and promote favorable particle growth.

There are many variations of the sedimentation process, encompassing a wide variety of commercially available equipment.

4. Precipitation, Flocculation, and Sedimentation Applications to Hazardous Wastes

The processes of precipitation, flocculation, and sedimentation are finding widespread application in the treatment of wastewater streams containing soluble heavy metals and colloidal hazardous substances. A summary of general wastewater treatment applications in a number of major industries is presented below.

a. Iron and Steel Industry. Wastewater streams from the iron and steel industry are characterized by a very high concentration of settleable suspended particles and a relatively low concentration of dissolved heavy metals, such as ferric iron, zinc, lead, chromium, and manganese. Sedimentation is currently in widespread use for the removal of suspended solids. Precipitation (usually with lime and alum) is used to remove heavy metals.

b. Aluminum Industry. Wastewater streams from the aluminum industry contain high concentrations of soluble fluoride salts. The commonly used treatment process entails precipitation as calcium fluoride (with lime), flocculation, and sedimentation to remove the fluoride as solid particles.

c. Copper Industry. Wastewater streams from copper smelting and refining contain a variety of soluble and colloidal heavy metals (arsenic, cadmium, copper, iron, lead, mercury) that can be removed, to varying degrees of effectiveness, by precipitation, flocculation, and sedimentation using either lime or sodium sulfide.

d. Metal Finishing Industry. Soluble salts of copper, nickel, cadmium, and chromium are removed from wastewater streams by precipitation, for example, by utilizing lime to form insoluble hydrated oxides followed by flocculation, and sedimentation. Chromium usually present as chromate or dichromate must first be reduced to the trivalent state so that the precipitation process will be effective.

e. Inorganic Chemicals Industry. Many manufacturing processes within the inorganic chemicals industry produce wastewaters that contain suspended solids and soluble heavy metals. Manufacture of titanium dioxide and chromium pigments produce such wastewaters. Precipitation, flocculation, and sedimentation are used to treat many of these wastewaters.

f. Sludge Thickening. The first step used in a sludge dewatering process is often simply a better sedimentation process commonly referred to as "sludge thickening" or "gravity thickening." In the gravity thickening, the sludge is sent to a type of clarifier in which the already settled solid particles are allowed to settle further and compact. Typically, the supernatant liquid is returned to the main clarifier that performs the initial liquid-solid separation, while the "thickened" sludge is drawn off and either disposed of or sent to further dewatering steps, such as vacuum filtration or centrifugation.

5. Environmental Considerations

Since precipitation, flocculation, and sedimentation processes are basically liquid-solid separation processes, two output streams will result -- a high-volume purified liquid stream and a low-volume slurried solids stream. There are usually no air emissions from the process. The processes do employ equipment that exposes large open surfaces of liquid to the atmosphere, and, if that liquid is other than water and is highly volatile or contains highly volatile components, air emissions could result.

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CHAPTER 6

CLOSURE EVALUATION

Chapter Outline

A. Closure Requirement

B. Closure Plan Evaluation

    1. Disposal Procedures

    2. Facility Decontamination Procedures

CHAPTER 6

CLOSURE

A. CLOSURE REQUIREMENT

The closure requirement for tank facilities (40 CFR 264.197) states that "At closure, all hazardous waste and hazardous waste residues must be removed from tanks, discharge control equipment, and discharge confinement structures." Also at closure, as throughout the operating period, unless the owner or operator can demonstrate, in accordance with Section 261.3(d), that the residue removed from his tank is not hazardous waste, the owner-operator becomes a generator of hazardous waste and must manage it in accordance with all applicable requirements of 40 CFR Parts 262, 263, and 264.

B. CLOSURE PLAN EVALUATION

The tank closure plan must incorporate: (1) procedures for removing hazardous waste from the tank, (2) disposal of the removed residuals, and (3) decontamination of the tank itself. The closure plan must be updated according to relevant facility changes.

Closure plan data needs and evaluation procedures for the closure of tank facilities are detailed in the guidance manual on closure and postclosure (Subpart G).[1] This chapter emphasizes, therefore, disposal of remaining wastes and residuals at closure and tank decontamination procedures.

1. Disposal Procedures

The disposal procedures for the remaining waste within the tank and waste residues should be described. The following information should be included:

a. volume of waste to be disposed of;

b. method of removal from the tank;

c. processing or treatment method if required prior to transport or disposal (i.e., neutralize, stabilize, solidify), advisability of a trial treatment test if the treatment process is untried for the waste;

d. volume of waste for processing/treatment;

e. volume of waste resulting from processing/treatment.

The closure plan should describe either one of the following scenarios and include additional information as noted.

a. Upon closure, the facility will be operated in a routine manner for onsite disposal of all remaining hazardous waste and for waste processing and treatment procedures. For onsite disposal, the final onsite disposal method should be supplied.

b. Upon closure, all waste will be removed and transported to another hazardous waste treatment, storage, or disposal facility. For offsite disposal, the following information should be supplied:

- method of transport to disposal site (i.e., truck, rail, water);
- distance of transport to disposal site;
- final disposal method (i.e., facility type, such as a secure landfill).

If the closure plan calls for a combination of both on- and off-site disposal, the quantity of waste to be disposed of by each method must be identified.

2. Facility Decontamination Procedures

At closure, the entire facility should be cleaned, and no hazardous materials should be left onsite. This includes cleanup or disposal of contaminated equipment, soils, and residues. The closure plan should include:

a. methods to test for contamination (laboratory procedures, kits, mechanical, electrical, or visual methods);

b. areas of facility to be tested or cleaned:

- tanks and other storage areas;
- all equipment used prior to storage or treatment in a tank, such as waste feed systems, by-pass systems, drainage systems, conveyors, containers used for transport;
- discharge confinement structures such as dikes;
- piping, pumps, valves, heat exchangers, compressors;

c. description of the testing, cleaning, and disposal procedures;

d. disposal methods for decontaminant solutions and residues;

e. labor force expected to perform decontamination (in-house or outside contractor).

Preparation steps before testing and cleaning (after the waste has been drained from the tanks) may include the following:[2]

a. ventilation and gas testing;

b. assurances for safe entry and exit;

c. inspection of safety equipment such as safety belts, respiratory equipment, and personal protective equipment;

d. removal of all sources of potential ignition of flammable vapors such as smoking, welding, internal-combustion engines, etc., from the area prior to initiating the cleaning operation.

The actual cleaning of tanks may involve the following steps. These procedures should ensure that hazardous wastes are not released to the environment and cleaning crews are adequately protected.[3]

a. Removal of Tank Contents. The waste can be pumped to other storage within the facility or to a tank truck for offsite handling. Following waste removal, all piping to and from the tank should be disconnected and dismantled or decontaminated.

b. Removal of Flammable or Toxic Vapors. Displacement of flammable vapor by nonreactive gas is a safe means to minimize hazards. The gases commonly used are carbon dioxide and nitrogen. Both may be obtained in portable form in cylinders and in tank trucks. Other methods such as displacement with air, steam, or water can be used when no potential flammable hazard is involved.

c. Removal of Residual Sludges. In some cases it may be difficult to removal all liquid or solid residues, as these residues may be trapped behind heavy scale or rust or may be too viscous for pumping. When an internal inspection indicates that such a condition exists, steam cleaning or chemical cleaning may be needed to remove the residues. These two methods are also useful in decontaminating the tank interior and any associated contaminated auxiliary equipment. Steam cleaning utilizes steam to vaporize the residues, and chemical cleaning uses any of a number of industrial solvents to dissolve the residues.

Testing soils for contamination may or may not be necessary depending on the facility's conditions. In the closure plan, the owner-operator should describe the criteria used to determine the amount of contaminated soil.

REFERENCES

1. Draft Guidance for Subpart G of the Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities. (Draft). International Research and Technology Corporation (IR&T), McLean, Virginia, for U.S. EPA, Office of Solid Waste, Washington, D.C., October 1980.

2. American Petroleum Institute. Guide for Inspection of Refinery Equipment, Chapter V. 3d ed. Washington, D.C., 1978.

3. "Cleaning Small Tanks and Containers." National Fire Protection Association, NFPA No. 327. Quincy, Massachusetts, 1975.

CHAPTER 7

HAZARDOUS WASTE TANK COSTS

The types of tanks to be used in the handling and processing of hazardous waste depends principally on the chemical composition of the wastes. For example, highly corrosive wastes would probably have to be stored in tanks made of fairly inert material such as fiberglass. On the other hand, noncorrosive wastes containing toxic materials such as lead or mercury may be stored in steel or concrete tanks.

There are generally 11 types of steel, concrete, wood, or fiberglass tanks presently available from manufacturers.. They are:

1. prestressed concrete tanks;
2. ground-level steel tank;
3. steel tanks with standpipes;
4. elevated steel water tanks;
5. fixed-roof oil storage steel tanks;
6. floating-roof gasoline steel tanks;
7. wood tanks, ground level;
8. underground steel tanks;
9. underground fiberglass tanks;
10. expansion tanks (ASME); and
11. water tanks with cypress roofs.

Although all of these tanks are not necessarily used for storing hazardous waste, they are included to indicate costs for various sizes and types of tanks. Table 7-1 presents cost data for the different types and sizes of tanks. These costs are to be used for general comparison purposes and not to prepare engineering design estimates. The total estimated cost for the tank includes material, installation, and manufacturer's overhead and profit; the estimated cost does not include piping, pumps, and foundations. In addition, a 10 percent markup is assumed on all equipment. Figure 7-1 is a graphic representation of the cost of steel and concrete tanks by type and capacity. The smaller capacity fiberglass tanks are shown in Figure 7-2.[1]

Cost data for two types of stainless steel tanks, Types 304 and 316, are presented in Figure 7-3. Included in the prices shown are standard nozzles (manhole cover and coupling connections).[2]

TABLE 7-1

COST DATA FOR TANKS BY TYPE AND CAPACITY (1979)

Type	Capacity (thousand gallons)	Total Cost ($ thousands)
Prestressed concrete	250	110
	500	180
	1,000	260
	2,000	390
	4,000	620
	6,000	850
Ground-level steel tanks	100	50
	250	60
	500	100
	750	140
	1,000	230
	2,000	320
	4,000	560
	6,000	1,010
	8,000	1,130
Steel tanks with standpipes, 100 feet to overflow	500	160
	750	200
	1,000	240
	1,500	330
	2,000	410
Elevated steel water tanks, 100 feet to bottom capacity line	50	110
	100	140
	250	190
	500	310
	750	440
	1,000	550
Fixed-roof oil storage steel tank	210	50
	1,050	130
	2,310	220
	4,200	360
	6,300	510
	9,450	730

TABLE 7-1 (cont.)

Type	Capacity (thousand gallons)	Total Cost ($ thousands)
Floating-roof gasoline steel tanks	210	60
	1,050	180
	2,310	270
	4,200	430
	6,300	570
	9,450	810
Wood, ground level, 2 inches, cypress	30	5
Wood, ground level, 2 1/2 inches, cypress	10	122
Wood, ground level, 3 inches, redwood or fir	20	16
	30	20
	45	25
Steel, underground, coated,	1, 7 gauge shell	
	5, 14" thick shell	3
	10, 14" thick shell	4
	10, 5/16" thick shell	5
	20, 5/16" thick shell	9
	30, 3/8" thick shell	150
Fiberglass, underground, not including manways or hold-down straps	2	34
	4	49
	6	51
	8	61
	10	75
	12	90
	15	11
	20	14

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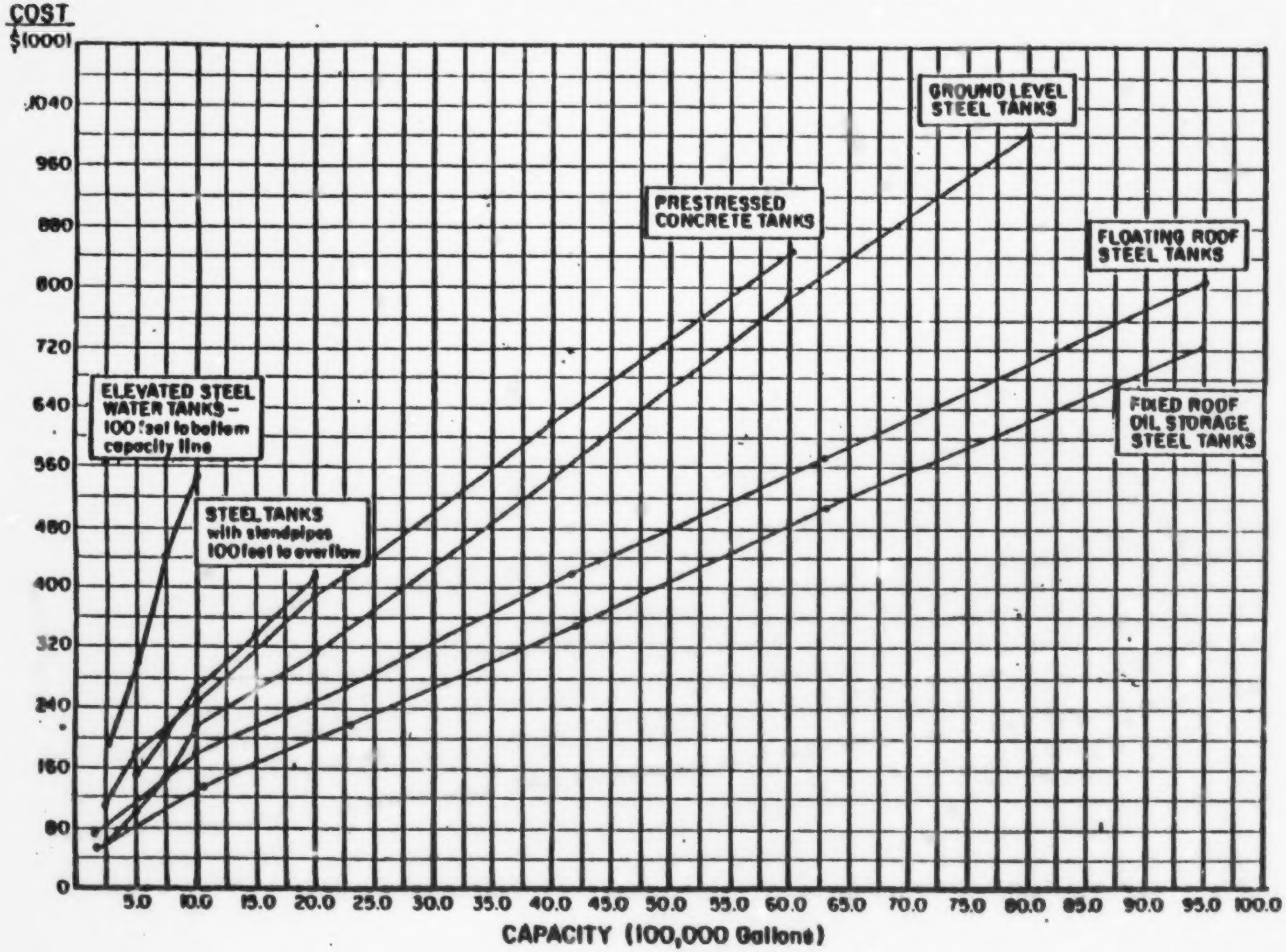
* This information is copyrighted by Robert S. Means Co. It is reproduced, with permission, from Mechanical and Electrical Cost Data -- 1979.

FIGURE 7-1

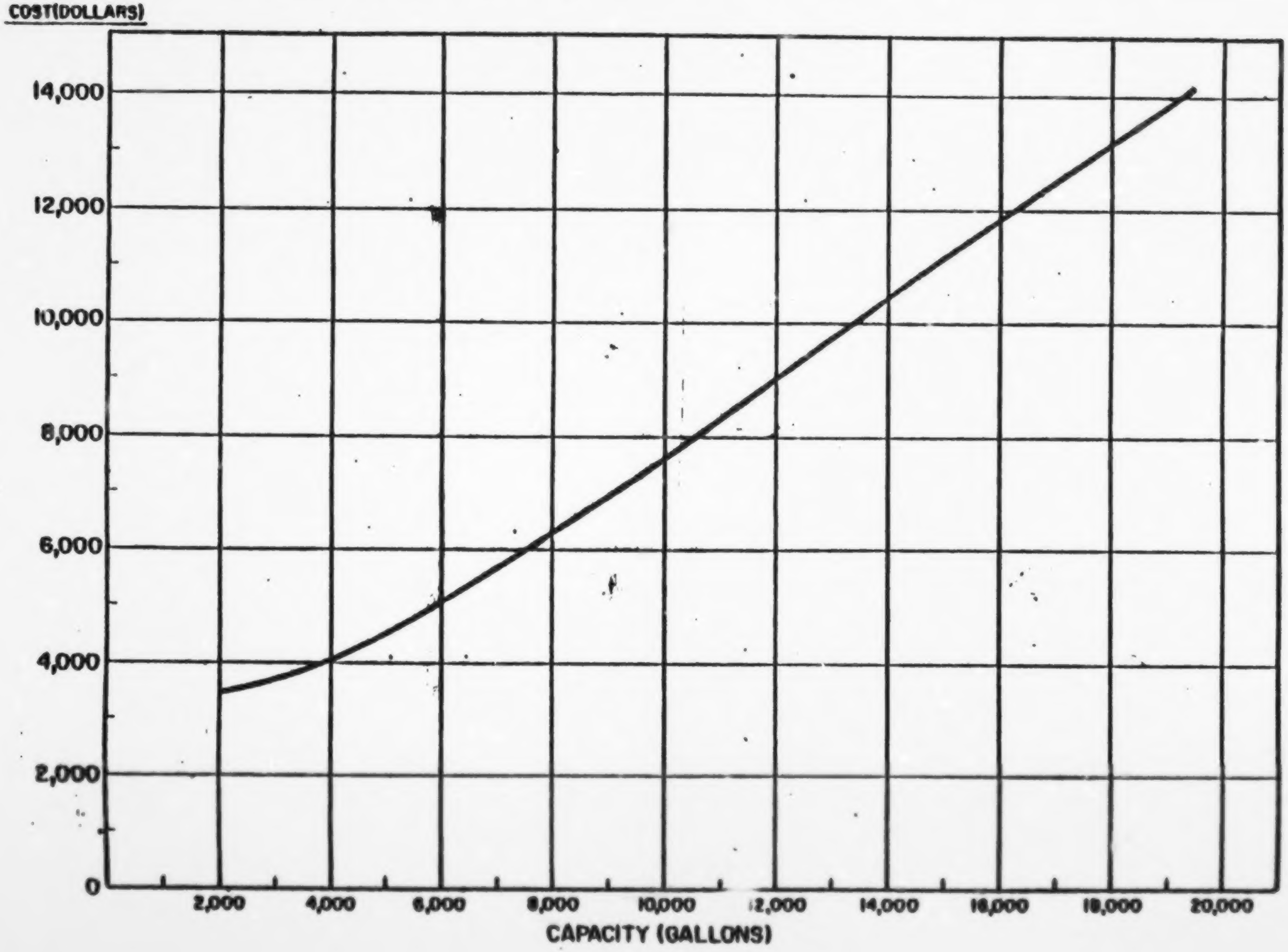
TANK COST DATA BY TYPE AND CAPACITY



Source: Means Mechanical and Electrical Cost Data–1979, Robert Snow Means Company.

FIGURE 7-2

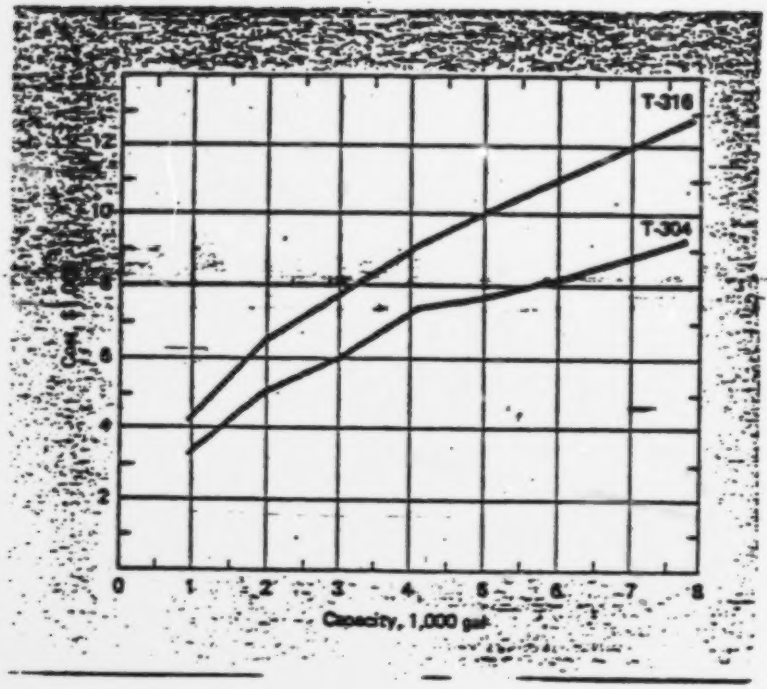
FIBERGLASS TANK COST DATA BY CAPACITY



Source: Means Building Construction Cost Data-1980,
Robert Snow Means Co.

FIGURE 7-3

Stainless Steel Tank Cost
Data by Capacity



T-316 and T-304 are two different types of stainless steel tanks

Source: Epstein, Lawrence D."Costs of standard vertical storage tanks and reactors," Chemical Engineering, 88 (14): 141, July 1981.

The tanks with the largest capacity are floating- and fixed-roof steel tanks. Capacities for these tanks range from approximately 200,000 gallons to nearly 9,500,000 gallons. Fiberglass tanks, on the other hand, seldom exceed a maximum capacity of 20,000 gallons.

There are numerous types and sizes of pipes that may be used in conjunction with tanks. The choice of a particular type of pipe is a direct function of the type and quantity of waste being handled. For example, an aluminum pipe may be inappropriate for a highly acidic waste. Instead, a more expensive corrosion-resistant pipe may have to be used. In addition, if the tank holds large volumes of waste, pipes of greater diameter will have to be used. Therefore, the type and quantity of hazardous waste handled by the tank will determine the particular type and size of the pipe to be used and, consequently, the cost. In general, piping costs at a tank farm facility can range as high as 50 percent of the total facility cost.

The above discussion has focused on the essential components of hazardous waste tanks, namely, the material and installation costs of the tanks. Other costs that should be considered include: the cost of pumps (e.g., material and energy costs), the cost of site preparation (e.g., foundation, construction, and labor costs), and other costs such as for vapor-recovery systems. These costs may vary significantly with the type of tank used and the geographical location.

REFERENCES

1. *Mechanical and Electrical Cost Data -- 1979*. Robert S. Means Co., Kingston, Massachusetts, 1979.

2. Lawrence D. Epstein. "Costs of Standard Vertical Storage Tanks and Reactors." *Chemical Engineering*, 88 (14): 141, July 1981.

APPENDIX A

TYPES OF TANKS USED FOR HAZARDOUS WASTE STORAGE

A. ATMOSPHERIC ABOVE-GROUND, COVERED TANKS[1]

Atmospheric tanks are used to store liquids having internal vapor pressure approximating atmospheric pressure at ambient storage temperatures. Vapor pressure is the pressure exerted by the vapors of that liquid. Pressure varies with temperature. Atmospheric tanks are equipped with vents that are designed to balance the inside pressure and outside atmospheric pressure to within a few ounces per square inch to preclude rupture. Numerous types of atmospheric tanks are described in the following sections.

1. Fixed-Roof Tank

A fixed-roof tank has a nonmovable roof. The simplest type is the cone-roof as shown in Figure 1. These tanks may be as large as 250 feet in diameter and 60 feet in height. A cone-roof tanks has two common variations, the umbrella-roof tank (Figure 2) and the dome-roof tank. The umbrella roof has segmental plates placed on meridian center lines; the dome roof has spherically curved roof plate segments.

2. Floating-Roof Tank

A floating-roof tank has a roof that floats above the surface of the stored liquid. The floating roof serves to reduce evaporation loss by maintaining a constant vapor space above the stored liquid. Some examples of floating-roof tanks are the pan, the annular-pontoon, and the double-deck, as shown in Figures 3, 4, and 5, respectively. The cross-sectional views are shown in Figure 6. The floating-roof and the tank wall are sealed by a shoe or plate pressed against the wall by springs, connected with a flexible membrane. An example of a seal is shown in Figure 7.

3. Covered Floating-Roof Tank

A covered floating-roof tank has a fixed roof combined with a steel pan floating roof inside. The fixed roof is usually a cone. These tanks are often built in heavy snowfall areas where an open-top floating roof may be insufficient to handle the load.

4. Variable-Vapor-Space Tank

A variable-vapor-space tank has a gas-holder device that can temporarily store expanding vapors. The lifter roof and the flexible diaphragm, shown in Figures 8 and 9, respectively, are the common types.

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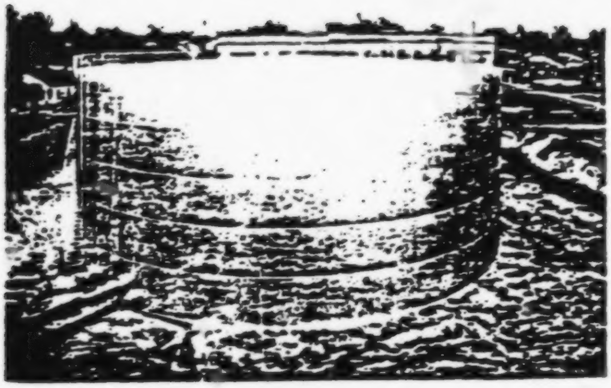


FIG. 1—Cone-Roof Tank.

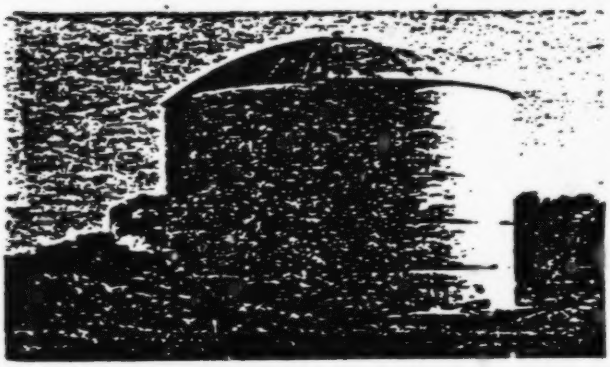
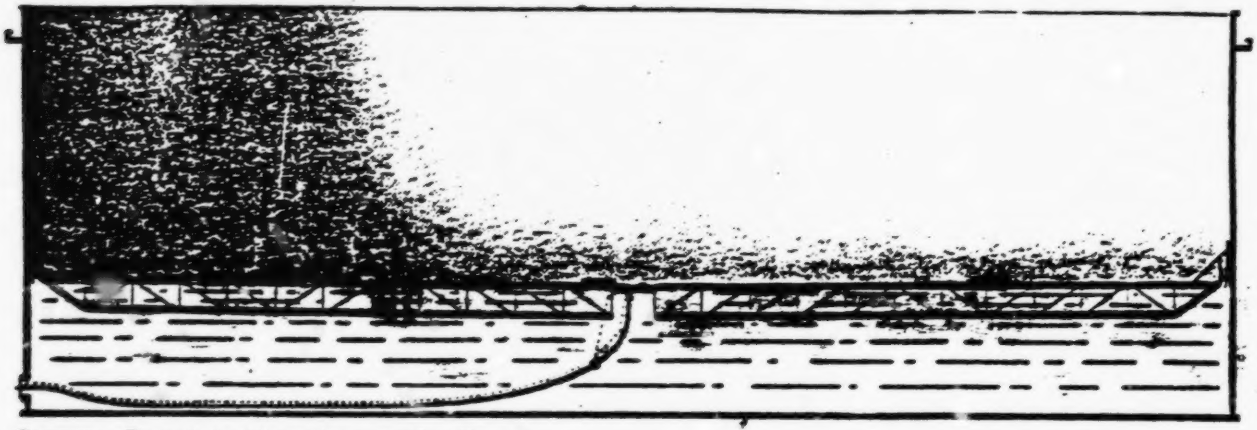


FIG. 2—Umbrella-Roof Tank.

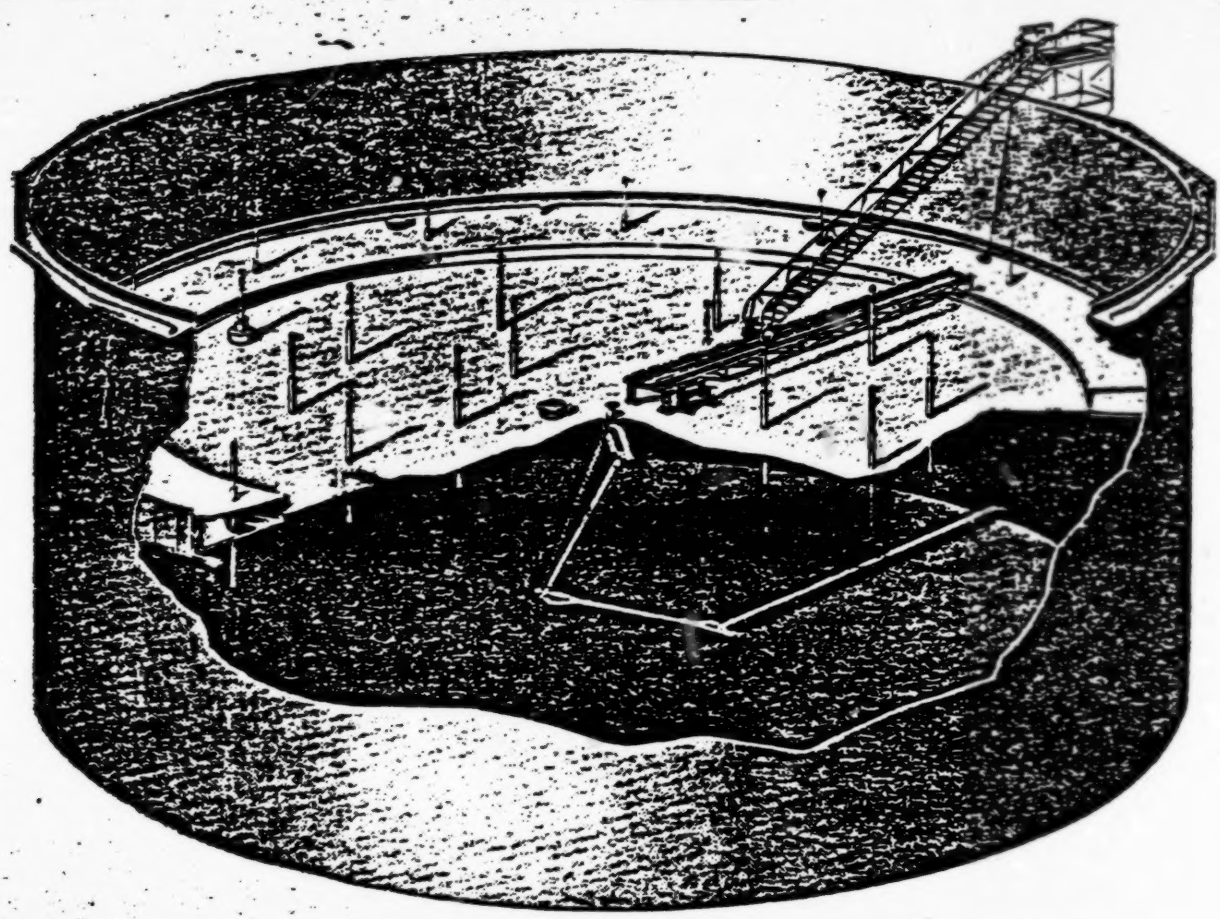
Guide for Inspection of Refinery Equipment, Chapter XIII, 3rd ed., Pub. no. 821-00013, p. 8, reprinted by courtesy of the American Petroleum Institute.



Courtesy: General American Transportation Corp.

FIG. 3—Pan-Type Floating Roof.

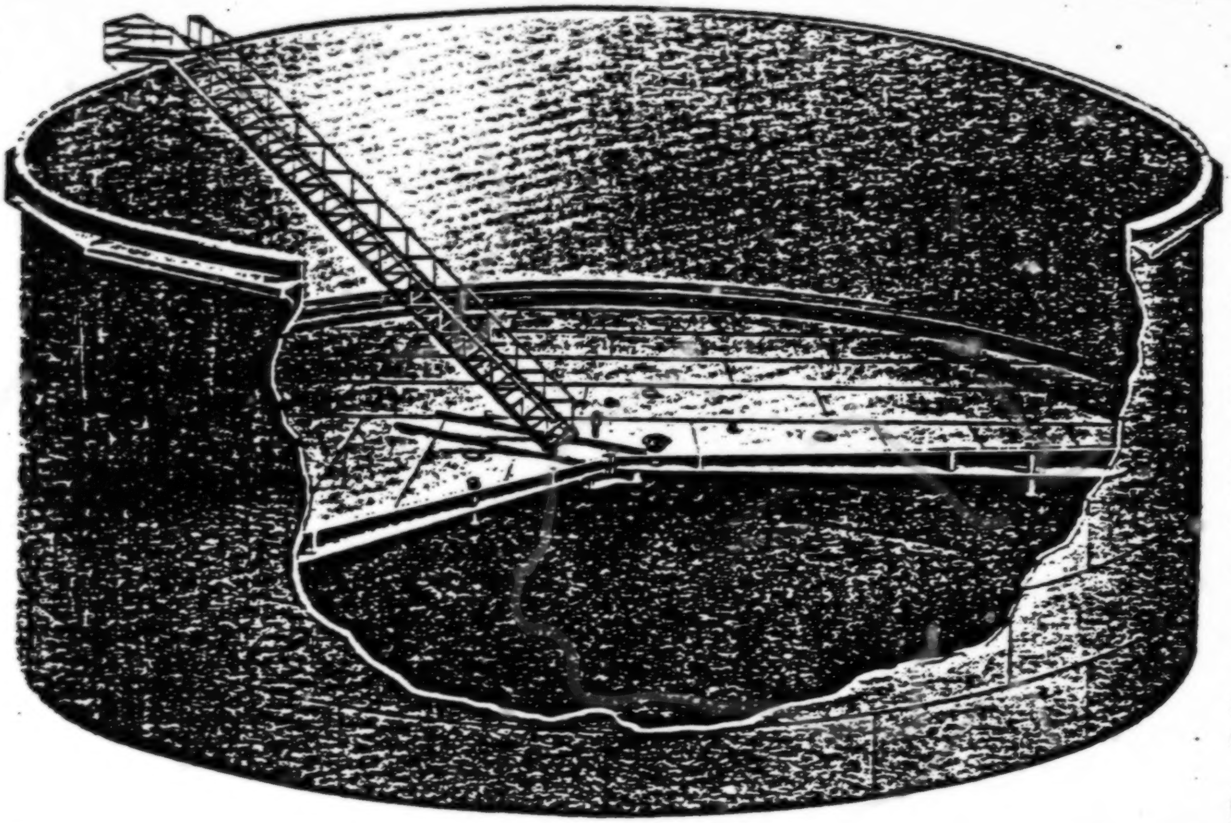
Evaporation Loss in the Petroleum Industry, API Bulletin 2513, 1959, p. 17, reprinted by courtesy of the American Petroleum Institute.



Courtesy: Chicago Bridge and Iron Company.

FIG. 4 —Pontoon-Type Floating Roof.

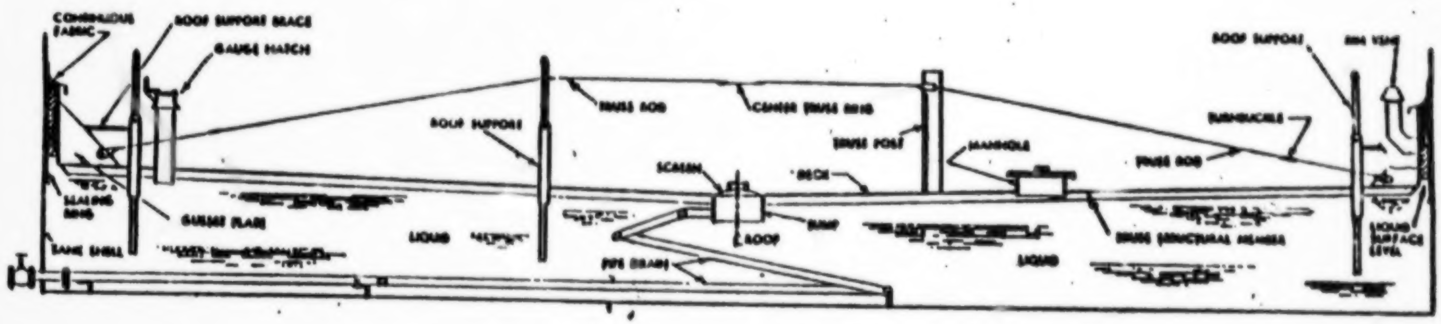
Evaporation Loss in the Petroleum Industry, API Bulletin 2513, 1959, p.17, reprinted by courtesy of American Petroleum Institute.



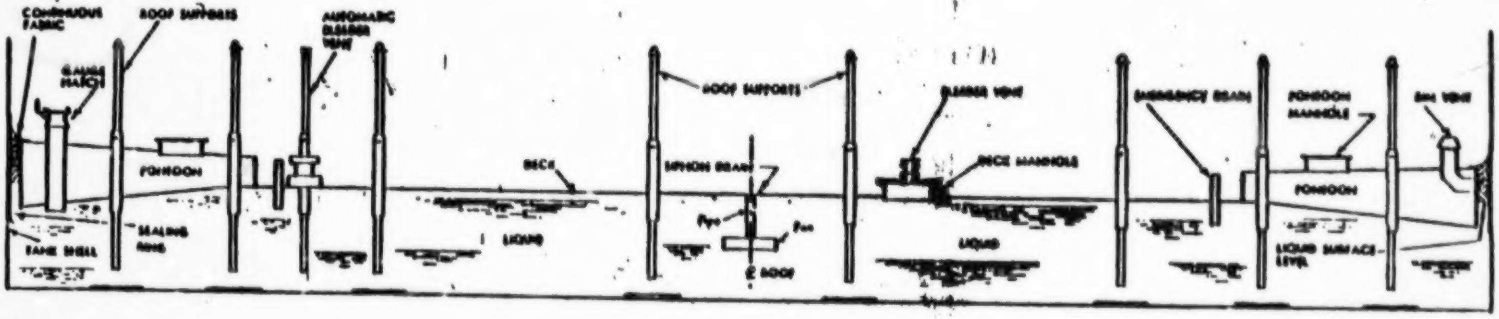
Courtesy: Hammond Iron Works.

FIG. 5 —Double-Deck Floating Roof.

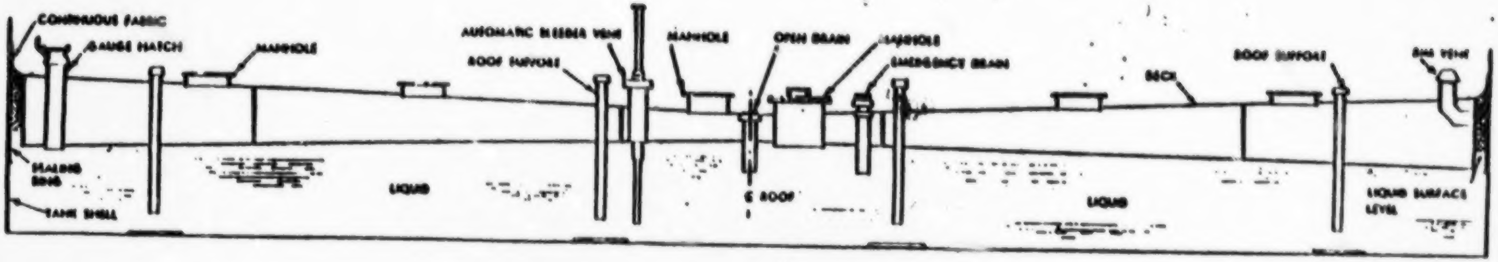
Evaporation Loss in the Petroleum Industry, API Bulletin 2513, 1959, p. 19, reprinted by courtesy of the American Petroleum Institute.


CONTINUOUS FABRIC
ROOF SUPPORT BRACE
GAUGE HATCH
TRUSS ROD
CENTER TRUSS RING
ROOF SUPPORT
RIM VENT
TURNBUCKLE
TRUSS POST
MANHOLE
TRUSS ROD
SCREEN
DECK
SEALING RING
GUSSET PLATE
LIQUID
SUMP
TRUSS (STRUCTURAL MEMBER)
LIQUID SURFACE LEVEL
TANK SHELL
℄ ROOF
PIPE DRAIN
LIQUID

PAN FLOATING ROOF


CONTINUOUS FABRIC
ROOF SUPPORTS
AUTOMATIC BLEEDER VENT
GAUGE HATCH
ROOF SUPPORTS
BLEEDER VENT
EMERGENCY DRAIN
PONTOON MANHOLE
RIM VENT
PONTOON
DECK
SIPHON DRAIN
DECK MANHOLE
PONTOON
Pipe
Pan
SEALING RING
TANK SHELL
LIQUID
LIQUID
℄ ROOF
LIQUID SURFACE LEVEL

PONTOON FLOATING ROOF


CONTINUOUS FABRIC
GAUGE HATCH
MANHOLE
AUTOMATIC BLEEDER VENT
ROOF SUPPORT
MANHOLE
OPEN DRAIN
MANHOLE
EMERGENCY DRAIN
DECK
ROOF SUPPORT
RIM VENT
SEALING RING
TANK SHELL
LIQUID
℄ ROOF
LIQUID
LIQUID SURFACE LEVEL

DOUBLE DECK FLOATING ROOF

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FIG. 6—Cross-Section Sketches of Floating-Roof Tanks Showing the Most Important Features.

Guide for Inspection of Refinery Equipment, Chapter XIII, 3rd ed., p. 9, reprinted by courtesy of the American Petroleum Institute.

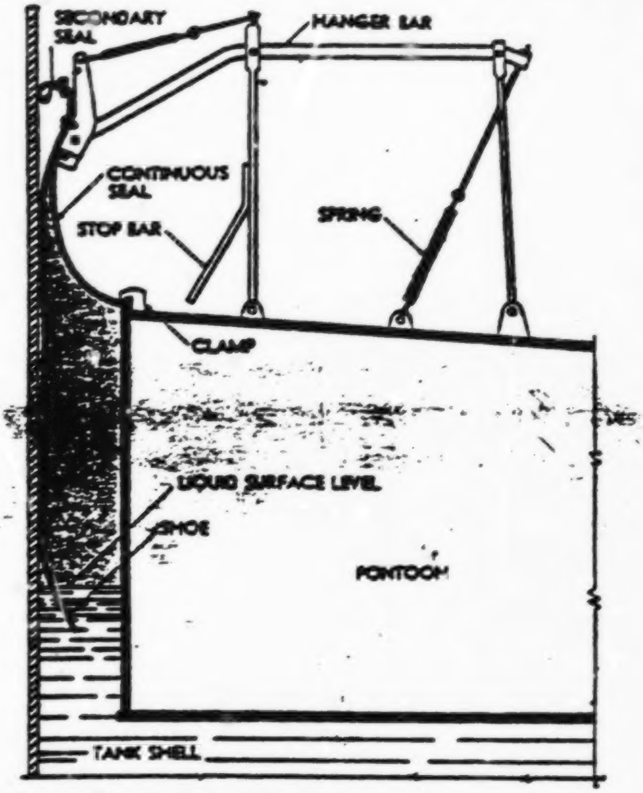

SECONDARY SEAL
HANGER BAR
CONTINUOUS SEAL
STOP BAR
SPRING
CLAMP
LIQUID SURFACE LEVEL
SHOE
PONTOON
TANK SHELL

FIG. 7—Floating-Roof Seal Using Coil Springs to Maintain the Seal.

Guide for Inspection of Refinery Equipment, Chapter XIII, 3rd ed., p. 10, reprinted by courtesy of the American Petroleum Institute.

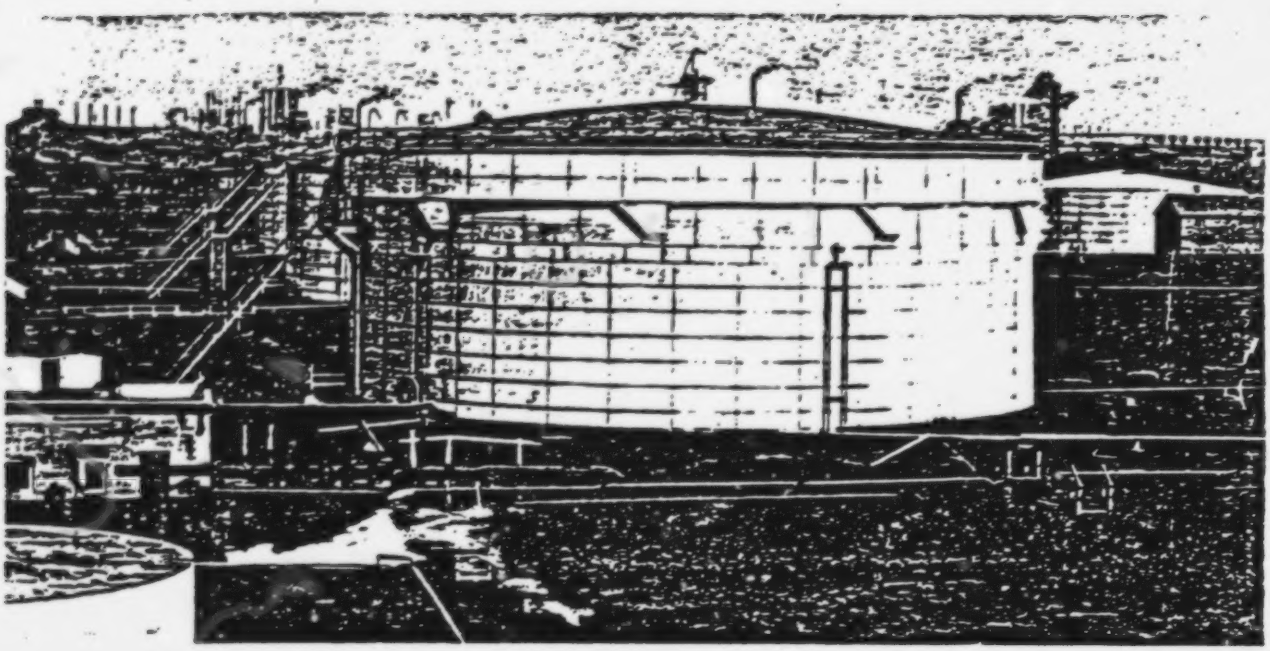
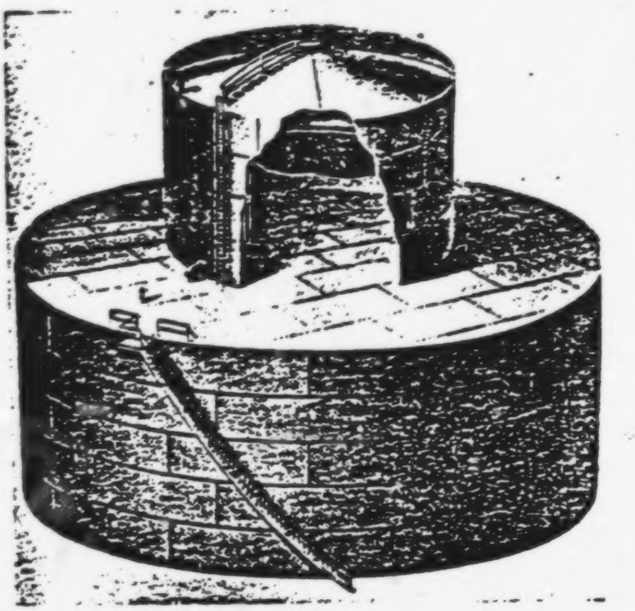


FIG. 8 —Lifter-Roof Tank.

Guide for Inspection of Refinery Equipment, Chapter XIII, 3rd ed., Pub. no. 821-00013, p. 11, reprinted by courtesy of the American Petroleum Institute.



Courtesy: Hammond Iron Works.

FIG. 9.—Flexible-Diaphragm Tank (Integral Unit).

Evaporation Loss in the Petroleum Industry, API Bulletin 2513, 1959, p. 21, reprinted by courtesy of the American Petroleum Institute.

5. Lifter-Roof Tank

A lifter-roof tank can have either a wet seal or a dry seal, and the roof can move up or down the tank shell as the vapor space expands or contracts. A typical design of the wet-seal lifter roof includes an annular space surrounding the shell containing a sealing liquid inside. The seal liquid can be water, light oil, or antifreeze depending on the climate, liquid solubility, and tank design. The actual seal is provided by a dip skirt that extends from the roof into the liquid. A dry-seal lifter roof design, as shown in Figure 10, is similar to the wet-seal design (Figure 11). It has rubber or dry seal instead of liquid.

6. Flexible-Diaphragm Tank

A flexible-diaphragm tank can be either a separate unit or an integral unit. It is essentially a fixed-roof tank with a flexible diaphragm attached to the inside of the shell. The diaphragm expands or contracts with the vapor volume.

7. Breather-Roof Tank

Breather-roof tanks provide expanded vapor space without using a loose external roof. Some examples of breather-roof tanks are the plain, balloon-roof, and vapor-dome tanks. A plain breather-roof and a balloon-roof tank, as shown in Figures 12 and 13, respectively, have flexible steel roofs capable of moving up and down within narrow limits. The balloon roof is capable of providing a greater change of volume. The vapor-dome roof tank has an added fixed dome with a flexible membrane attached to the wall inside. The membrane can be moved flexibly to provide changes in volume.

8. Plain Cylindrical Tank

A plain cylindrical tank is used to store small quantities of liquid at atmospheric pressure (see Figures 14 and 15). It usually has a flat head and can be placed either vertically or horizontally.

B. LOW-PRESSURE ABOVE-GROUND, COVERED TANKS

Low-pressure tanks are used to store liquids having a vapor pressure up to 15 psig at ambient temperatures. Two types of low-pressure tanks are described below.

1. Hemispheroidal Tank

A hemispheroidal tank is similar to a cone-roof tank except that the bottom and top are curved to withstand pressure. Plain and noded hemispheroidal tanks are shown in Figures 16 and 17.

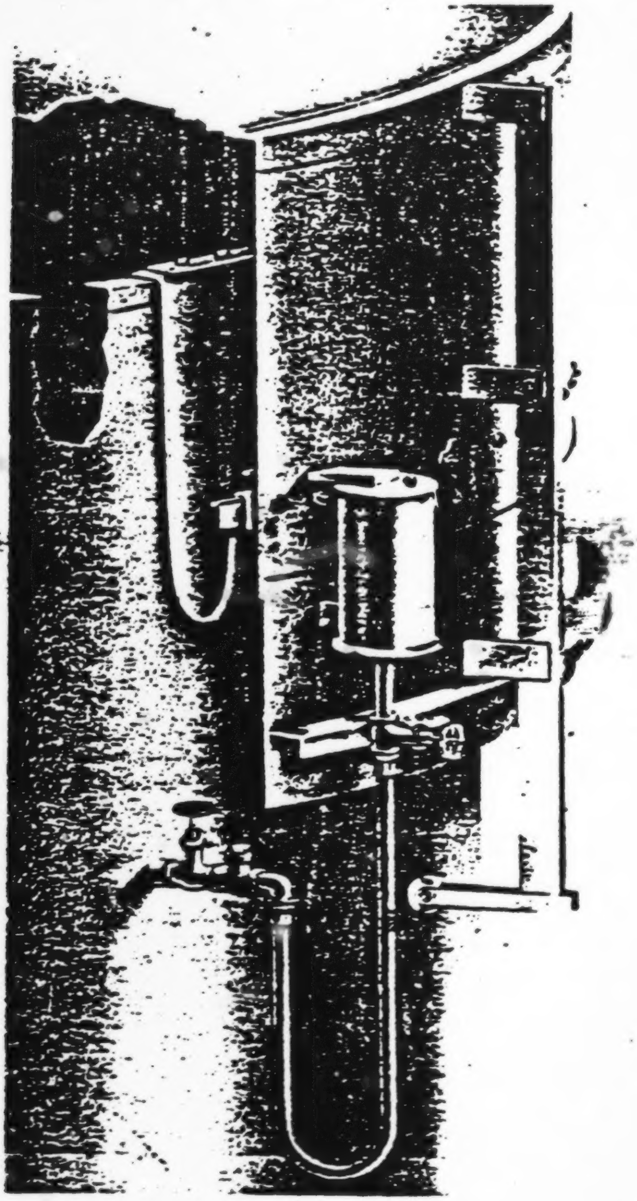
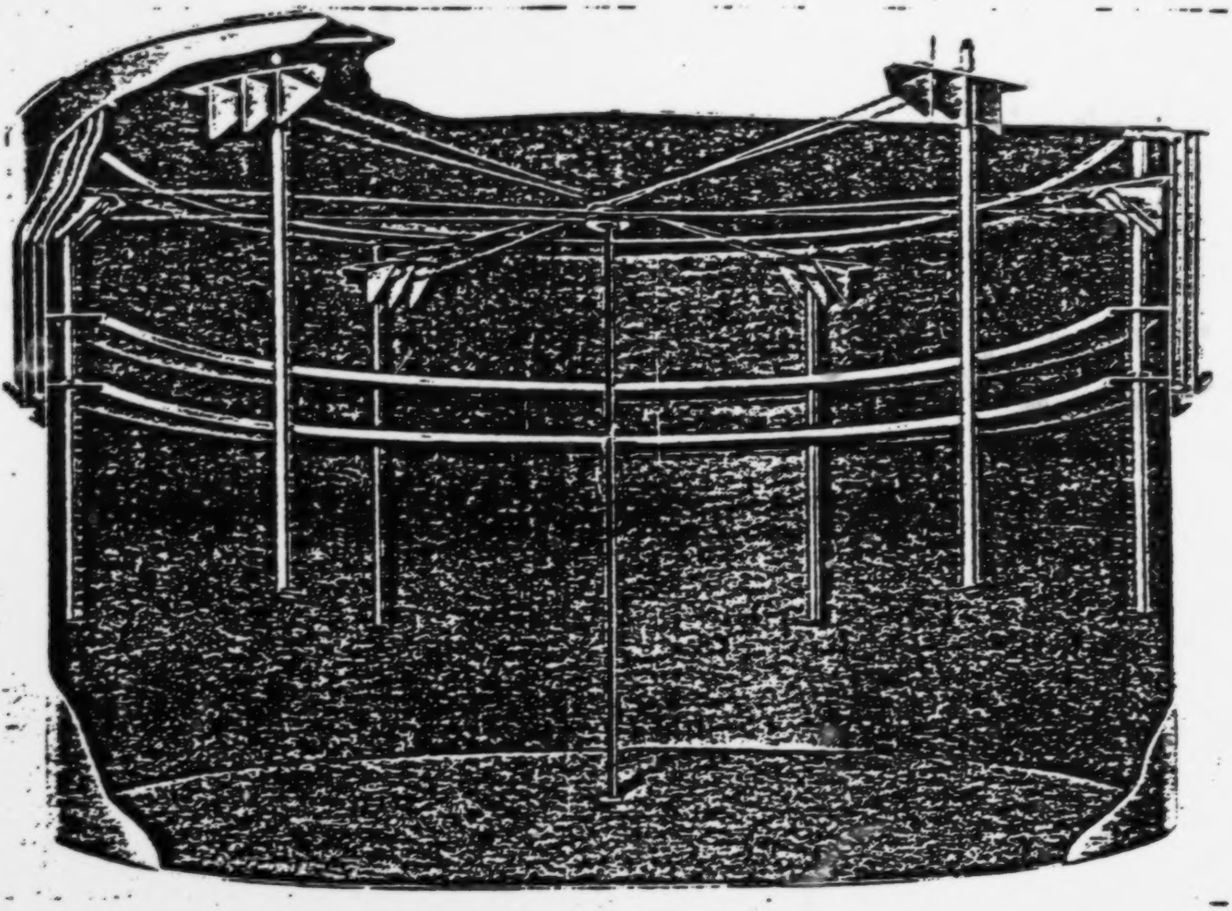


FIG. 10 —Dry-Seal Lifter Roof.

Guide for Inspection of Refinery Equipment, Chapter XIII, 3rd ed., Pub. no. 821-00013, p. 12, reprinted by courtesy of the American Petroleum Institute.



Courtesy: Graver Tank and Manufacturing Company, Inc.

FIG. 11—Wet-Seal Lifter Roof.

Evaporation Loss in the Petroleum Industry, API Bulletin 2513, 1959, p. 20, reprinted by courtesy of the American Petroleum Institute.

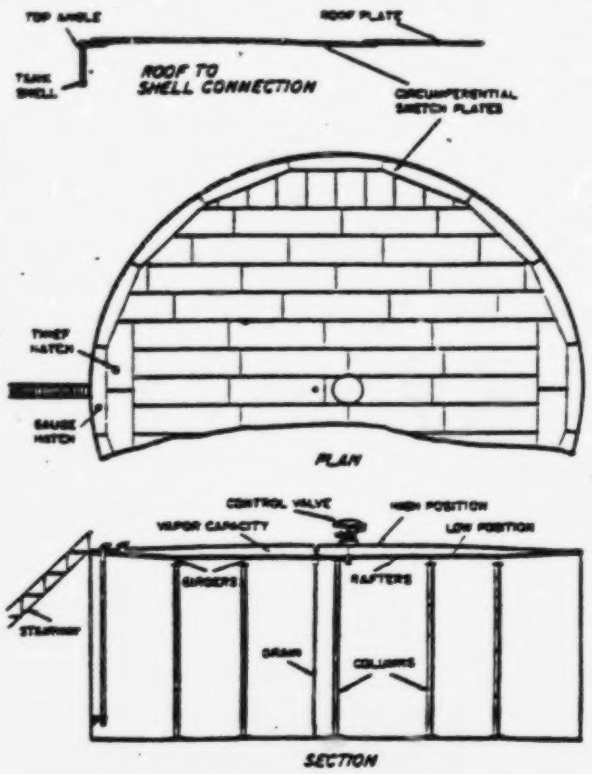

TOP ANGLE
ROOF PLATE
TANK SHELL
ROOF TO SHELL CONNECTION
CIRCUMFERENTIAL SKETCH PLATES
THIEF HATCH
GAUGE HATCH
PLAN
CONTROL VALVE
HIGH POSITION
VAPOR CAPACITY
LOW POSITION
GIRDERS
RAFTERS
STAIRWAY
DRAIN
COLUMNS
SECTION

FIG. 12 —Plain Breather-Roof Tank.

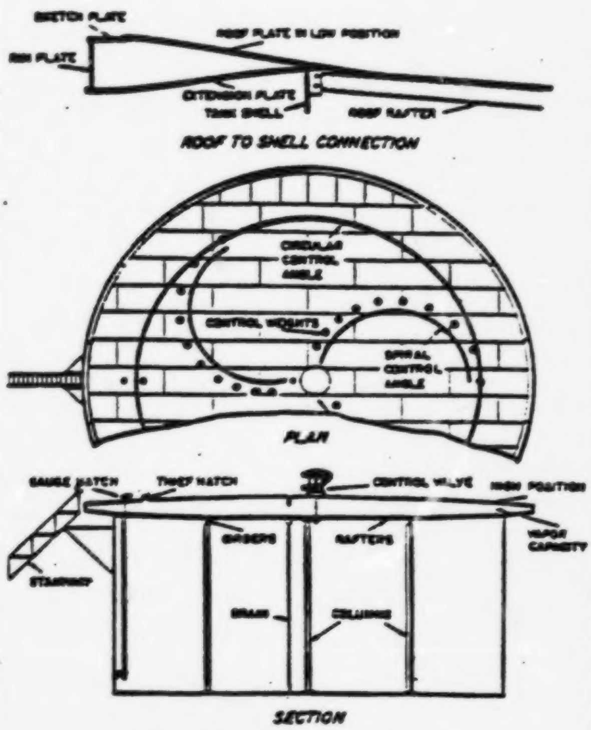

SKETCH PLATE
ROOF PLATE IN LOW POSITION
RIM PLATE
EXTENSION PLATE
TANK SHELL
ROOF RAFTER
ROOF TO SHELL CONNECTION
CIRCULAR CONTROL ANGLE
CONTROL WEIGHTS
SPIRAL CONTROL ANGLE
PLAN
GAUGE HATCH
THIEF HATCH
CONTROL VALVE
HIGH POSITION
GIRDERS
RAFTERS
VAPOR CAPACITY
STAIRWAY
DRAIN
COLUMNS
SECTION

FIG. 13 —Balloon-Roof Tank.

Guide for Inspection of Refinery Equipment, Chapter XIII, 3rd ed., Pub. no. 821-00013. p. 12, reprinted by courtesy of the American Petroleum Institute.

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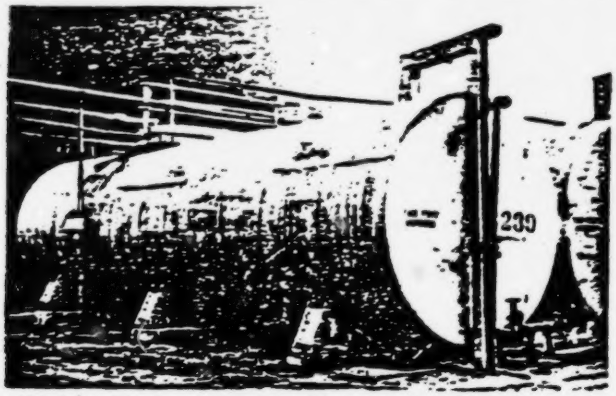


FIG. 14 —Horizontal Tank (Riveted) Supported on Steel Cradles.

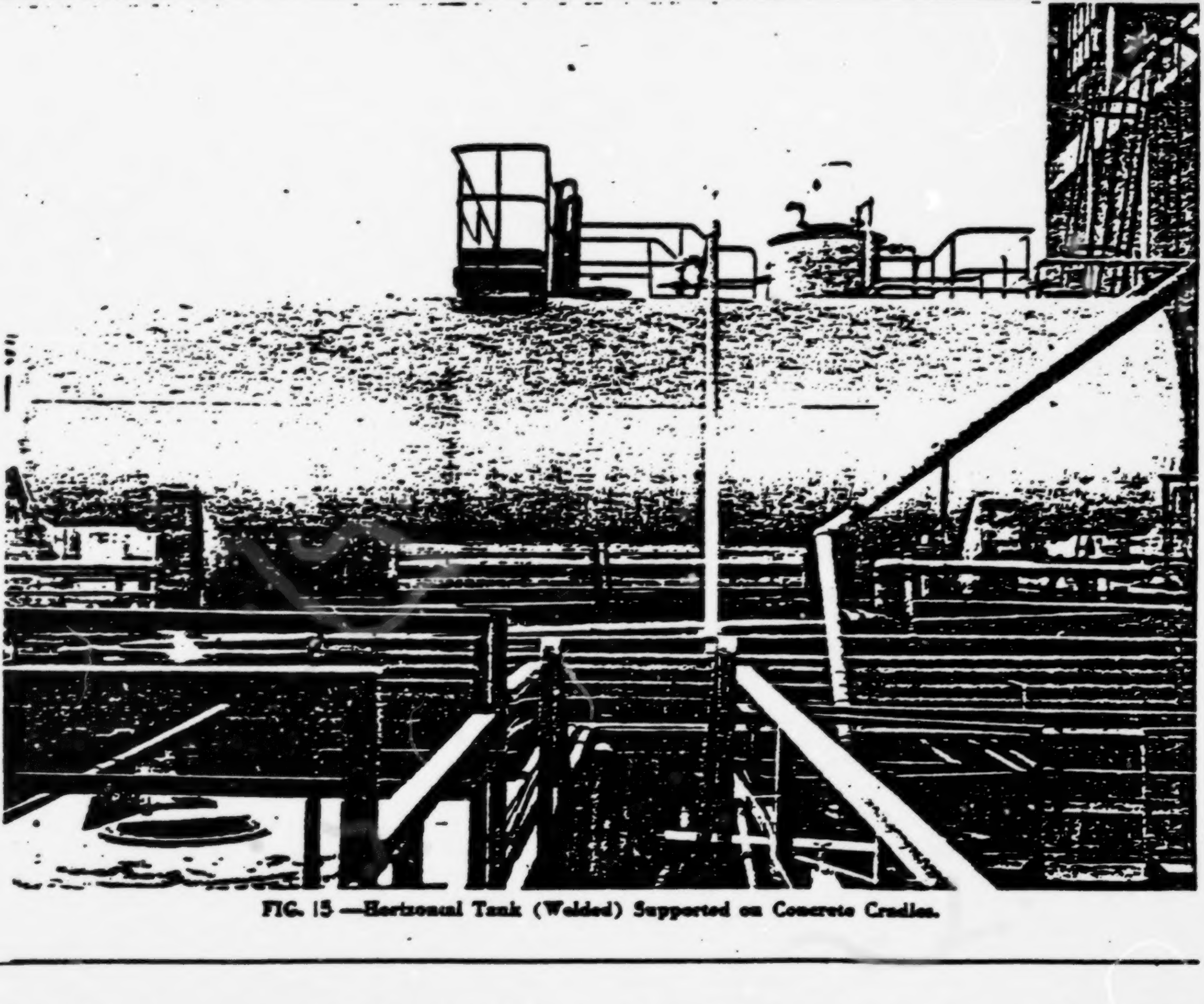


FIG. 15 —Horizontal Tank (Welded) Supported on Concrete Cradles.

Guide for Inspection of Refinery Equipment, Chapter XIII, 3rd ed., Pub. no. 821-00013, p. 14, reprinted by courtesy of the American Petroleum Institute.

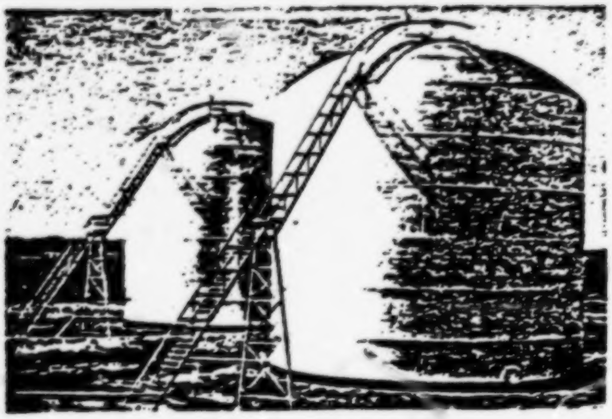
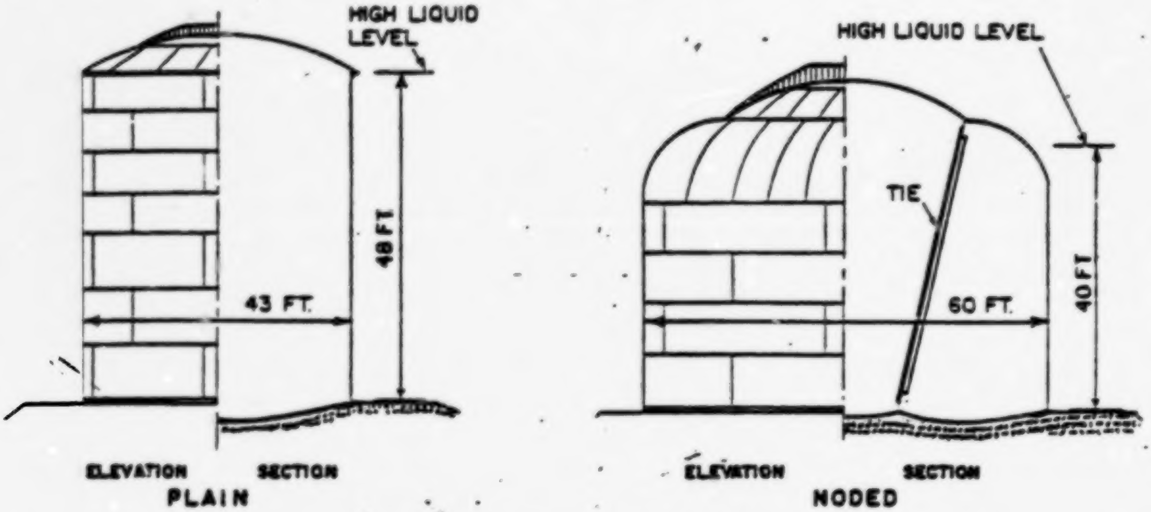


FIG. 16 —Plain Hemispheroids.



HIGH LIQUID LEVEL
48 FT
43 FT.
ELEVATION
SECTION
PLAIN
HIGH LIQUID LEVEL
TIE
40 FT
60 FT.
ELEVATION
SECTION
NODED

FIG. 17 —Drawings of Hemispheroids.

Guide for Inspection of Refinery Equipment, Chapter XIII, 3rd ed., pp. 14-15, reprinted by courtesy of the American Petroleum Institute.

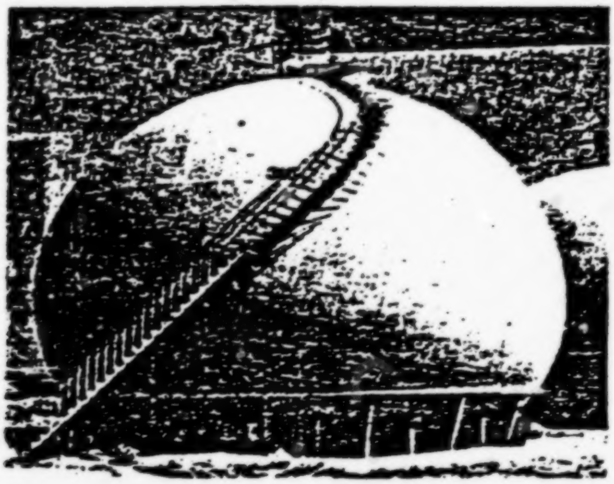


FIG. 18—Plain Spheroidal Tank.

FIG. 19 —Noded Spheroidal Tank.

Guide for Inspection of Refinery Equipment, Chapter XIII, 3rd ed., p. 16, reprinted by courtesy of the American Petroleum Institute.

2. Spheroidal Tank

Spheroidal tanks are used under the same conditions as hemispheroidal tanks and are normally used for the storage of large volumes (see Figures 18 and 19).

C. UNDERGROUND TANKS

Underground tanks are used most frequently for small bulk storage and are often horizontally cylindrical in shape. The major advantages of underground storage are safety and aesthetics. Corrosion of underground steel tanks has been a disadvantage in the past, but proper corrosion protection is now feasible with cathodic devices or special coatings. Another disadvantage is the difficulty in determining tank leakage and the consequent danger of ground-water contamination. Polyester- and fiberglass-reinforced tanks are commonly used underground and are priced competitively with steel tanks. The permit requirements currently exclude the use of covered underground tanks that cannot be entered for inspection for treatment or storage of hazardous waste.

D. UNCOVERED TANKS

Uncovered tanks and basins can be used to store hazardous wastes that are relatively nonvolatile. Ground-water contamination is a major consideration in the evaluation of basins.

REFERENCES

1. American Petroleum Institute. Guide for Inspection of Refinery Equipment, Chapter XIII. 3d ed. Washington, D.C., 1972.

2. American Petroleum Institute. Bulletin 2513. Evaporation Loss in the Petroleum Industry -- Causes and Control. Washington, D.C., 1973.

APPENDIX B

SUBSURFACE AND FOUNDATION CONSTRUCTION

A. SITES REQUIRING SPECIAL CONSIDERATIONS

When facilities are constructed in the following areas, they require special structural considerations:[1]

- hillside sites, where part of a tank may be on undisturbed ground or rock and part on fill or other material, or where the depth of required fill is variable;
- sites on swampy or filled ground, where layers of muck or compressible vegetation are at or below the surface, or where unstable or corrosive materials may have been deposited as fill;
- sites over layers of plastic clay, which may temporarily support heavy loads but may settle excessively over long periods of time;
- sites adjacent to water courses or deep excavations, where lateral stability of the ground is questionable;
- sites immediately adjacent to heavy structures, which distribute some of their load to the subsoil under the tank site, thereby reducing its capacity to carry the additional load without excessive settlement;
- sites where tanks may be exposed to floodwaters, which could result in possible uplift, displacement, or scour.

If the subgrade is weak or inadequate to carry the load of a full tank, construction under the tank bottom is necessary. One or more of the following general methods may be used:

- remove the objectionable material and replace it with other suitable and compact material;
- compact the soft material with short piles or by preloading with overburden of earth or other material suitably drained;
- compact the soft material by draining off the water, if practicable;
- stabilize the soft material by chemical methods or injection of cement grout;
- drive bearing piles or construct foundation piers to serve as a reinforced slab on which to distribute the load of the tank.

Fill material used to replace objectionable materials and to build a suitable base (e.g., to build up the grade to a suitable height) should be of high quality. It should be free of vegetation and organic matter and should not contain substances, such as cinders, that could cause corrosion of the tank bottom. The fill should be thoroughly compacted.

B. FOUNDATION TYPES[2]

When the properties of the underlying soil are inadequate to support the load of a full tank, a foundation is needed. Piles may be used under the foundation for support. Piles can be made of steel, reinforced concrete, or concrete-filled steel shells. Appropriate foundations are especially important when the facility location is in an earthquake zone, a marshy area, or an otherwise unstable area.

C. EARTHEN FOUNDATIONS[1]

If subsurface conditions indicate that it is unnecessary to construct a substructure to support the tank, suitable foundations may be constructed from earthen materials. The performance requirements for an earthen foundation are identical to those associated with artificial material foundations. Specifically, the foundation should:

- provide a stable plane for the support of the tank;
- limit overall settlement of the tank grade to values compatible with allowance provided in the design for connecting piping; and
- provide adequate drainage.

D. TANK GRADES[2]

It is suggested that the tank be constructed above the surface of the surrounding ground. This will provide for suitable drainage, help keep the bottom of the tank dry, and, even if some settlement occurs, elevate the tank above the surrounding surface.

It is suggested that the top 3 to 4 inches of the finished grade consist of clean sand, gravel, crushed stone, or some similar inert material that can be readily shaped to the proper contour. Where fill beneath the tank is likely to wash out in the event of a bottom leak, 1/2 to 1 inch of gravel is recommended for a minimum depth of 3 inches. During construction, the movement of equipment and materials across the grade will mar the surface of the softer materials. These irregularities should be corrected before the bottom plates are in place for welding.

In order to preserve the contour during construction and to protect the tank bottom against ground moisture, the finishied grade may be oiled or stabilized in some other manner. Caution should be exercised in assuring that quantity or kind of material used for this purpose does not create welding difficulties or a risk of galvanic corrosion.

It is suggested that the finished tank grade be crowned from the outer periphery to the center. A slope of 1 inch in 10 feet is suggested as a minimum. Because the amount of crown will affect the lengths of roof-support columns, it is essential that the tank manufacturer be fully informed of the slope in advance.

REFERENCES

1. American Petroleum Institute. Standard 650, Welded Steel Tanks for Oil Storage. Appendix B, 6th ed. Washington, D.C., 1970.

2. American Petroleum Institute. Guide for Inspection of Refinery Equipment. Chapter XII. 2d ed., Washington, D.C., 1975.

APPENDIX C

TANK ANCILLARY FEATURES

A. PUMPS[1]

Pumps are necessary for all tank storage/treatment facilities. The cost of pumping can be a major factor in plant design and operation.

There are three broad classes of pumps: centrifugal, rotary, and reciprocating. Table 1 summarizes pump classes and types.

Several factors must be considered when selecting a pump to handle hazardous wastes. These factors include: capacity, pump head, nature of liquid handled, cost, and materials of construction.

1. The pump capacity requirement is determined by the liquid volume to be handled. A design safety factor is needed in case the flow exceeds the normal capacity. A stand-by pump is recommended when the flow of a particular stream cannot be interrupted.

2. The pump head requirement is primarily determined by the height the liquid must be lifted and friction losses exerted by piping and fittings.

3. The nature of the liquid handled, i.e., viscosity, volatility, corrosiveness, and amount of solids in suspension, will determine the type of pumps to be used and the construction material.

4. Cost factors in part dictate the pumping scheme or type of pump acceptable to a facility. Comparison of cost factors may allow the owner-operator to secure the lowest annual cost per gallon of liquid pumped. Dependability, ease of maintenance and repair, and flexibility are other factors.

5. Materials used in construction are important in the design of service pumps. Factors include corrosion-erosion resistance when transporting acids, alkalies, slurries, and other liquids; ease of installation, operation, and maintenance; and dependability. For example, a typical centrifugal pump for handling acid and slurry can be made of materials such as lead, stainless steel, solid plastic, or solid rubber. When special designs are not required, rubber, teflon, or neoprene base coverings are available for the casing and impeller.

The permit writer is referred to an enginering textbook[2] for illustrations on pump head and power requirements.

TABLE C-1

PUMP CLASSES AND TYPES

CLASS	TYPE
Centrifugal	Volute
(Single-stage and multistage)	Diffuser
	Regenerative-turbine
	Vertical-turbine
	Mixed-flow
	Axial-flow (propeller)
Rotary	Gear
	Vane
	Cam and piston
	Screw
	Lobe
	Shuttle-block
Reciprocating	Direct-acting
	Power (including crank- and fly wheel)
	Diaphragm
	Rotary-piston

B. FITTINGS

Valves are fittings that serve to regulate the flow of fluids and isolate piping for maintenance without interfering with the normal operation. The selection of fittings to handle hazardous wastes is primarily based on the compatibility of the construction materials with the wastes (see Section 5). The permit writer is referred to References 2 and 3 for details on fittings.

C. HEAT EXCHANGERS

Heat exchangers are devices that are used to transfer heat from one fluid to another. Design variations are numerous, but always consist of the transfer of heat from a hot phase to a cold phase with the two phases separated by a solid boundary.

Shell and tube heat exchangers are probably the most commonly used types of exchangers. The design is usually based on the Tubular Exchanger Manufacturers Association (TEMA) standards.[4] The American Petroleum Institute's Standard 660[5] supplements TEMA standards for refinery services. The permit writer is referred to References 2, 3, and 4 for drawings and required heat transfer area determinations.

D. COMPRESSORS[2,3]

There are two kinds of compressors: positive-displacement and centrifugal. Reciprocating and rotary compressors are positive-displacement types. Fans and blowers are centrifugal compressors. Fans and blowers operate at low pressure so that gas volume compression at inlets and outlets is essentially equal. Fans are simply movers of gas. They are classified by the direction of air flow: radial, centrifugal, or axial.

REFERENCES

1. T.G. Hicks and T.W. Edwards. Pump Application Engineering. New York: McGraw-Hill, 1971.

2. Principles of Unit Operations. New York: John Wiley and Sons, 1960.

3. R.H. Perry and C.H. Chilton, eds. Chemical Engineers' Handbook. 5th ed. New York, McGraw-Hill, 1973.

4. Tubular Exchanger Manufacturers Association Standards. 5th ed. New York, 1968.

5. American Petroleum Institute. Standard 660. Heat Exchangers for General Refinery Services. 2d ed. Washington, D.C., 1972.

APPENDIX D

APPURTENANCES AND SAFETY EQUIPMENT

In general, tanks at hazardous waste facilities should be equipped with process process nozzles, service nozzles, and safety equipment.

1. Inlets and Outlets

- inlet nozzles must be adequate to handle the incoming waste at the design linear velocity;
- outlet nozzles must be adequate to handle outgoing waste at the design linear velocity;
- vent connections (depending on the type of tank) must be able to maintain the pressure of the tank according to tank specifications, such as atmospheric or low pressure;
- overflow connections (to prevent tank bursting) must be equal or larger than the inlet nozzle;
- drain connections should be located at the bottom of the tank to allow for emptying the tank's contents by gravity.

The sizing of process nozzles depends on the properties of the fluid handled. Properties to be considered include:

- percent of solids by weight;
- volumetric flow rate;
- minimum and maximum linear velocity; and
- pressure drop at the entrance and the exit of the nozzle.

Tanks are equipped with several instrument nozzles that provide conduits for measuring devices and indicators.

2. Instrumentation

- high liquid level (HLL), which indicates when the liquid level has reached the design capacity of the tank;
- low liquid level (LLL), which indicates when the liquid level has reached the low mark of the design capacity;
- level alarm -- high (LAH), which indicates when the liquid has reached the dangerous level. If the situation is not rectified, the waste will overflow from the tank.

- level alarm low (LAL), which indicates when the liquid level has reached the dangerous level. If the situation is not rectified, pump cavitation can occur because of pumping air instead of liquid.

Level indicators/controllers are illustrated in Figures 3-2 and 3-3 of the text. The time needed to fill the tank from LLL to HLL is called the retention time of a tank. The working or design capacity of the tank is equal to the volumetric flow rate (gallons per minute) times the retention time. The volume of waste stored in a tank should not exceed the tank design capacity.

3. Service Ports

- manway to provide entrance into a tank to perform inspection and maintenance work;
- temperature indicator port;
- pressure gauge port;
- sampling port.

Temperature and sampling ports are located at a point that is representative of conditions within the tank. Usually, they are located slightly above the expected LLL of the tank.

4. Safety Equipment

- pressure safety valves are designed to open when the pressure exceeds a predetermined level to preclude rupture of the tank. Common types of pressure safety valves include pilot-operated relief valves, pressure relief valves, or pressure vacuum valves.

APPENDIX E

SECONDARY CONTAINMENT

Currently, EPA's hazardous waste regulations do not require a secondary containment system for tanks that treat or store hazardous waste. These systems are, however, effective means for detecting and containing leaks and spills and are included in the design of many facilities. Some types of secondary containment are:

- runoff and leachate collection systems;
- peripheral diking systems; and
- liner systems.

Runoff and Leachate Collection Systems. These systems should be constructed of materials compatible with the waste and should be designed to include:

- a slope of greater than 1 percent away from the tank or the collection point;
- a collection point where runoff or precipitation can be routed so that it can be removed;
- capacity equal to the volume of the largest tank or 10 percent of the volume of all the tanks in the containment system and allowance for preciptation; and
- sufficient freeboard for sumps (if applicable).

Peripheral Dike Systems. Peripheral drainage collection can serve two purposes: it can prevent precipitation from entering the contained system, and it can contain leaks, runoff, and precipitation within the system. An acceptable design for a tank diking system should include the following:

- a capacity equal to the volume of the largest tank or 10 percent of the volume of all tanks (whichever is greater) in the containment system;
- walls that are designed to be liquid tight and to withstand a full hydrostatic head. The slope of earthen walls should be consistent with the soil's angle of repose;
- piping (which passes through dike walls) that is liquid tight and designed to prevent excessive stresses as a result of settlement;
- relatively impermeable ground within the dike area to preclude ground-water or surface-water contamination;

- a drain (such as drain pipes or grates) with control valves for the systematic collection and drainage of runoff, leakage, and precipitation from the diked area. Alternatively, a sump system that can be drained utilizing a portable pump may be installed;

- diked area should be kept free of drums, debris, etc.

For structural stability purposes, earthfill dikes should have side slopes of horizontal to vertical no greater than 2 to 1. Additionally, a cutoff joining the base of the dike with the underlying soil is recommended to "key" the dike into the indigenous soil.

Liners. A liner is a continuous layer of natural or man-made materials, beneath or on the sides of a containment system, that restricts the downward or lateral escape of hazardous waste, hazardous waste constituents, or leachate. The purpose of a liner for a tank storage facility is to prevent hazardous waste from coming in contact with the soil or surface or ground water. Liners may or may not be used at a facility. If liners are used, they may be found under or on top of the containment area or in other unique applications. A variety of natural and synthetic materials are available for use as liners. Their selection is generally based on the following factors:

- degree of impermeability (and thickness) required;

- hydraulic head of waste;

- availability of the material;

- costs.

See EPA's technical resource document titled Lining of Waste Impoundment and Disposal Facilities[3] for further information on liners.

REFERENCES

1. "Flammable and Combustible Liquids." National Fire Protection Association, NFPA 30, 1981. Quincy, Massachusetts, 1980.

2. Oil spill prevention control and countermeasure plan review. A training program planned and presented by Rice University, the Universities of Texas and Houston, and the U.S. Environmental Protection Agency. The Pace Company, 1975.

3. Lining of Waste Impoundment and Disposal Facilities. Office of Water and Waste Management. U.S. EPA SW-870. September 1980.